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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3.1.2

Japan

ESTABLISHMENT OF HYDROLOGICAL NETWORK FOR RIVER BASIN DEVELOPMENT

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Japan

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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ESTABLISHMENT OF HYDROLOGICAL NETWORK FOR RIVER BASIN DEVELOPMENT

Mr. Akihiko Tsuchiya, Ministry of Construction

I. ADMINISTRATIVE PROBLEMS RELATING TO DEVELOPMENT OF WATER RESOURCES

1. It is a very obvious fact that water is indispensable to human life, but people living in civilized society now do not appreciate it so much. On the other hand, to people living on deserts and solitary islands in the ocean, and in areas of small precipitation, water is more precious than money. In other words, it may be said that the relation between water and man is subject to the difference in the natural conditions. Furthermore, this relation differs according to the age; it cannot but change greatly as a result of a change in the industrial structure and advancement in the mode of living.

2. From the standpoint of water utilization, the rate of utilization is low in spite of the fact that water is indispensable to man. For a long time it was merely used for irrigation and municipal water services. It was only very recently that water was taken up as one of the important resources of the secondary industry and its importance was first recognized. In areas where the relative importance of the primary industry is very great, the utilization of water is primarily for agriculture, and particularly when the type of agriculture is one which consists principally of rice crop production as in Southeast Asia, there can be no agriculture unless utilization of water is taken into consideration. Conversely speaking, it may be said that it is agriculture itself which is the most affected by floods. It is natural that the characteristics of floods should differ very much according to the meteorological and geographical conditions and also that transitions in the economic and social backgrounds of a country should bring about changes in her people's way of thinking concerning floods. At the same time, political and administrative measures cannot but alter in accordance with such changes.

3. If we look back on the history of the system for controlling and utilizing water and that of water administration in Japan as an example, we can well understand the above statements. First, flood control projects have been a matter of concern of the successive governments. In fact, such projects in Japan may be traced back to A.D. 300 or so. In modern times, the River Law was enacted in the Meiji era, and the administration of water has been performed mainly from the standpoint of flood prevention. That is to say, politically the primary concern has been flood prevention. As regards the water utilization aspect, in formulating an administrative plan of agricultural water utilization, the practice has been to take it up chiefly from the standpoint of land improvement, the stand of the farmers themselves not always being positively considered. The tendency has been to look upon water as something existing naturally. Secondly, the remarkable growth of demand for water in recent years, that is, the increase in demand for municipal service water due to the change in the mode of living and for industrial water due to the expansion of the production scale is making it necessary to drastically reform the legislation relative to water. In other words, there is an increasing recognition of the fact that water is something produced by science and technics and, moreover, that it is not meant for any specified people or social circles but should be utilized for the public benefit. In the field of administrative system too, the time has come to work for its integration and adjustment to

meet the situation.

4. In Japan, the administration of water is now divided among several Ministries according to the purpose ——— Ministry of Construction (flood control), Ministry of Agriculture and Forestry (irrigation), etc., and legal rights and interests are asserted by the respective interested groups. Under these circumstances, it is extremely difficult to attain integrated utilization of water resources based on a national viewpoint. However, when we consider the essential nature of administration, the most important thing is to protect the national and public interests. The recent trend in the administration for development and utilization of water resources is that it must be done based on modern scientific techniques. This is seen in the unified development projects to be carried out by the Water Resources Development Corporation with the aim of promoting coordinated development and utilization for each of the river systems in areas where the demand for water is conspicuously high, as provided for in the recently enacted Law for Promoting Development of Water Resources.

5. Administrative problems relating to development of water resources vary with the country according to her historical background. We must know that there are involved many factors which cannot be solved merely by technical measures for water utilization.

II. HYDROLOGICAL OBSERVATION IN JAPAN

6. Hydrological observation generally means the measurement of precipitation and the observation of water-stage and discharge of the river. Seen from the standpoint of purpose, observation stations may also be divided in another way into two types: those established for the purpose of flood control and those for water utilization. Of course, some are established for the double purpose and some others for water utilization are intended not for the general water utilization but for a special purpose of water utilization. With regard to the business of such observation in Japan, the general observation of precipitation is conducted by the Meteorological Agency in accordance with the Meteorological Business Law and the outflow of the main rivers by the Ministry of Construction. The observation of the outflow of smaller rivers is conducted by the respective local public bodies (i.e. prefectures) which are responsible for their administration. Needless to say, observation for other purposes, for instance precipitation measurement intended for irrigation and water stage observation for power generation, is also conducted by the Ministry of Agriculture and Forestry and power companies respectively.

7. An outline of these observation networks in Japan is given in Table 1 so

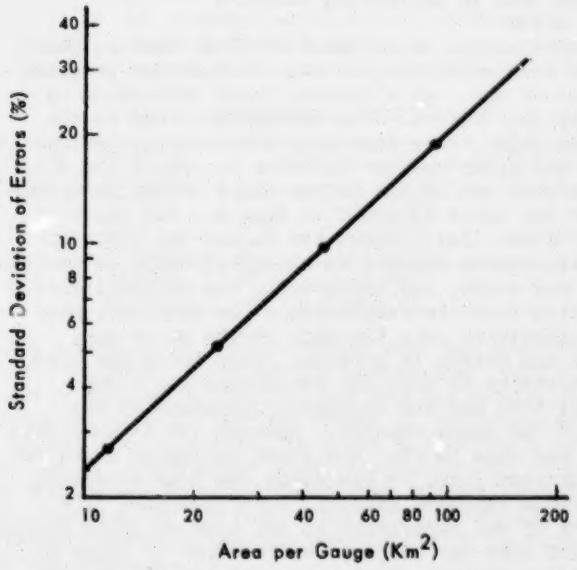
Table 1. Numbers of Hydrological Observation Stations throughout Japan

	Meteorological Agency	Ministry of Construction	Ministry of Agriculture and Forestry	Ministry of International Trade and Industry
Precipitation measurement stations	2,022	1,300	679	3
Discharge observation stations	0	515	0	24

	Maritime Safety Agency or Defence Agency	National railways	Prefectures, cities, towns and villages	Power companies	Others	Total
Precipitation measurement stations	35	313	2,066	717	415	7,550
Discharge observation stations	0	0	273	435	20	1,267

as to show their scales. According to the Table, the average density of the precipitation measurement stations is 49 km^2 per station and that of the discharge observation facilities is 1 station for every 70 km of river length. As there are different organs in charge of the precipitation measurement facilities, it sometimes happens that few observation stations are placed at the same point, and so it is necessary to reduce the figures in their analysis or evaluation. It is a very difficult question on what basis the density of these observation networks should be decided. In deciding the most economical network which attains the accuracy necessary for the specified purpose, the geographical and meteorological conditions should be taken into consideration.

8. Let us consider establishing a precipitation measurement network for the purpose of developing water resources. In this case the aim of the precipitation measurement network is to obtain a long-range and macroscopic grasp of the quantity of water available from the river system. Recently, the Public Works Research Institute of the Ministry of Construction conducted a study of the relation between the average rainfall in the mountain district of the basin and the density of the precipitation measurement station network. The study, by utilization of the 31 precipitation measurement stations established in the area of 373.6 km^2, analyzed the relation between the area governed by one observation station and the standard deviation of the relative error from the correct value by observing many a continuous rainfall, the results being given in Fig. 1. It is considered that this relation changes with the total area of the basin and that the accuracy is improved with the increase of the area of the basin. Mr. Ray K. Linsley refers in his book to the results of the similar analysis made by the U.S. Weather Bureau. Considering the largeness of the basin area, a similar tendency is observed there. In Fig. 1, 10% in the standard deviation corresponds to 50 km^2 of area governed by one station, which density will be generally sufficient for calculation of the average precipitation in the basin. These values represent records in the mountain districts of Japan which, under the influence of typhoons and 'Baiu' fronts, are subject to local changes and where the conditions are different according to the locality. For other regions, it will usually be possible to enlarge the governing area per station.



9. Water-stage observation stations and discharge observation stations are usually operated by the Ministry of Construction or local public bodies. The primary object of the observation is to utilize the results for flood control, or, more concretely, flood alarm, river improvement, etc. In recent years, however, it has become necessary to give full consideration to rational allocation of water resources in order to meet the increasing demand for water, and so it is natural that the arrangement or placing of the stations should now be different from that in the days when flood control was the only consideration. With regard to the method of working

out a coordinated plan of the demand and supply of water, we may follow this method: ——— for a river system, to select 1 or 2 discharge observation stations as basic stations, to select 2 or 3 years when water dearth was severe out of the past ten years on the basis of the obtained data of discharge, and to examine the relation between supply and demand on the basis of the flow at the water dearth. In selecting the said basic stations, the two following conditions should be considered: (a) spot where the river has just entered the plain coming down from the mountain district and where the effect of the water supply and drainage in the upper stream can be neglected in planning the demand and supply of water, and (b) that the hydrometry data cover a long period. This method has been adopted in Japan taking into consideration the geographical conditions and the situation of water utilization of the country. In analyzing water resources for the use in the lower reaches, the water use for irrigation in the upper reaches may be neglected, because most part of the water used for irrigation flows underground and rejoins the main stream. Except in special cases like diversion in the upstream, industrial water and domestic water are usually taken in the alluvial plains after the river has passed through the mountain district in this country. Therefore, the said basic stations are very effective for analysis of the supply-demand relation.

10. In paragraphs 8 and 9 were explained the rules or standards for locating observation stations. Such standards should vary according to the geographical and climatic conditions, to the actual situation of supply and demand of water and to the plan. They must be selected so as to be arranged rationally to meet the respective purposes.

III. ANALOGUE COMPUTER USED IN ESTIMATING FLOODING OF THE KITAKAMI RIVER

11. As a link in the chain of comprehensive development of river basins, there have been worked out and carried out many multi-purpose dam construction programs in this country since the termination of war. As a result, flood prevention by means of dams has become more popular than before. One example is found in the case of the Kitakami river basin, for which three dams have been constructed and two others are to be constructed in the upper reaches in order to reduce the discharge of the main stream by 2,000 m^3/sec out of the design flood discharge 9,000 m^3/sec at Ichinoseki. An outline of the basin is shown in Fig. 2. The basin of the Kitakami lies between the Ou and the Kitakami mountain chains forming an elongated shape extending north and south, and accordingly the rainfall distribution there is complicated. In addition, many big tributaries join the main stream at so many points and affect it greatly. Such being the case, much prudence is required concerning the flood control plan and the discharge operation of the dams in the upper reaches. However, it demands much labor and time to find the flood discharge curve for a downstream point by operating the dams according to various supposed rainfall distributions. The results of our experience at the time of three floods revealed that the computation requires 50 hours by use of the digital electronic computer (FACOM 128B Relay Type). Accordingly, a new analogue flood computer is being manufactured aiming at (a) establishing a rational plan for improving the rivers of the Kitakami System, (b) reducing the time needed for flood forecast and improving the accuracy of forecast, (c) attaining rational and unified operation of the five dams, etc.

Fig. 2

(see page 6)

12. Details of the computer are omitted on account of space consideration, but in the following will be given an explanation of the pluviometry network which serves as the basis of calculation: ——— With respect to the river channel, the area is divided into 7 blocks along

the main stream as shown in Fig. 3. In computing the precipitation, the retarding effect of the transversal inflow that contributes to the mainstream in each block was considered. In Fig. 3, the precipitation measurement stations are also given. From the records of the stations, the average rainfall in the basin was obtained by Thiessen's method. Then 2-4 other stations closely related to them were selected and the formula expressing the daily average rainfall in the basin was estimated on the basis of the records of these stations. For instance, the relation between the records of the station in Block III and the average daily rainfall of the basin was as shown in Table 2. Based upon this, two representative stations were considered as shown in Table 3. The precipitation measurement stations in all the

Table 2. Relation between Representative Precipitation Measurement Stations and Average Daily Rainfall

No. of block	Name of precipitation measurement station	Correlation coefficient	
		Baiu type	Typhoon type
III	Dake	0.959	0.849
	Toyozawa	0.890	0.865
	Ōhazama	0.930	0.950
	Namari	0.887	0.941
	Ontoku	0.929	0.938
	Shimetsukeumaushi	0.955	0.955
	Hanamaki	0.916	0.956
	Tase	0.901	0.949
	Tōno	0.957	0.864
	Ashigashe	0.872	0.769

Coefficient for representative precipitation measurement station:

$I = \alpha a_i + \beta b_i + \gamma c_i$

I: Average areal daily rainfall

α, β, γ : Coefficient

a_i, b_i, c_i : Daily rainfall in a, b, c

Table 3. Correlation Coefficient

No. of block	Name of station		Coefficient in formula to calculate average daily rainfall	
			'Baiu' type	Typhoon type
III	Dake	α	4.5963368	2,2244161
	Tase	β	2.2095607	3.9603779
	Hanamaki	γ	3.2642935	3.8070117
III	Namari	α	2.8109638	4.2709466
	Tono	β	6.9871075	4.7058778

basin numbered 48, the governing area per station being 145 km^2.

13. In actual calculation, the rainfall distribution is given for the rerpective areas of the basin, and for the dam the discharge curve so that the water stage and discharge curve at various points of the main stream in the lower reaches may be obtained. In this case, in order to find in a short time the rational operation of the dam it is necessary that calculation can be made automatically for obtaining the respective values variant with the precipitation in the upper reaches and with the operation of the dam. However, no computer has been utilized so far for calculation involving the dam operation. It is scheduled to install more facilities for the purpose.

FIGURE 2. KITAKAMI RIVER BASIN

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Fig-3 Thiessen network in the Kitakami River

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Agenda Item : A. 3. 4. 1

Sweden

A SEWAGE SYSTEM CONSUMING VERY LITTLE WATER

By Gunnar ESSUNGEN,
Civil Engineer,
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Sweden

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No. 595 A SEWAGE SYSTEM CONSUMING VERY LITTLE WATER

A.3.4.1.

by

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Sweden

The population of cities and towns is growing at an accelerating rate. At the same time there is an increasing demand for better sanitation. An adequate supply of pure water is essential for good sanitation, lowered infant mortality and greater longevity. A pure water supply, however, is dependent upon more than availability or otherwise of good water sources: it also involves the purification of sewage water. The more people who live in an area, the more the sewage and the greater the need for strict protection of water sources.

The conventional sewerage system is based on water as a conveyance for waste. The foul water flows in pipes which slope from the collection area to the treatment plant. Liquid sewage from domestic districts consists of waste water (from bath, kitchen sink and home laundry) and of W.C. soil. Sewage from the W.C.'s is composed of small quantities of solids mixed with large quantities of water, necessary to keep the solids moving. Domestic waste water and W.C. soil are discharged in the same conduits. This means that waste water, which is safe under normal conditions, is mixed with objectionable matter from the W.C.'s; the latter is responsible for about 80% of all the organic impurities found in the mixed sewage water and virtually all the pathogenic bacteria.

The Swedish Engineer Joel Liljendahl has invented an improved sewerage for water closets. In this new system the excrements and urine are transported through plastic tubes connected to a vacuum tank. After use, each closet bowl is automatically cleansed through flushing with about .2 gallons of pressurized water. This very small amount of water forms together with the waste a homogeneous slurry and, under the influence of the air pressure difference, this is conveyed in the shape of spaced plugs to said vacuum tank. The waste may then directly or after a decay process be utilized as a fertilizer or other soil improver (Figure I).

The new type of W.C.-stool is simple and reliable in running (Fig. II). Contrary to the conventional W.C.-stool no mobile parts are under water in the vacuum stool.

In the Liljendahl system the total daily water consumption pro person amounts to 1 to 2 gallons as compared with 10 to 20 gallons in conventional systems.

The degree of vacuum in the tank necessary for the transport can be conventionally attained by the use of comparatively small vacuum pumps driven by electric motors or by internal combustion engines. The operation costs of these pumps are also very low. For example, three 3-h.p. pumps will suffice for a community of 4,000 inhabitants.

The discharge plastic pipes in the Liljendahl system may have a diameter of only 40 to 50 millimetres instead of 100 to 150 millimetres in the conventional systems. The plastic pipes are simpler to make and save an enormous amount of material. For instance, a 330-foot main with 40 branches weighs only about 110 lb. in the Liljendahl system, as compared with 3,300 lb in the conventional system with cast iron pipes. To a certain extent the pipes may be disposed horizontally or in an uphill direction. From the point of view of building construction the Liljendahl system involves considerable advantages. Plastic pipes, being flexible, can be easily guided past obstacles that would have meant cutting, jointing or the use of bends in cast iron or concrete pipes. Furthermore, the plastic pipes take a minimum of space and are always easy to fit in frame construction. They withstand blows, subsidence, earth tremors, rock-blasting, etc. and enjoy a longer life than conventional piping, especially as they do not rust, which means fewer repairs.

The Liljendahl system simplifies modular construction and prefabricated methods of building. Where drainage is to be installed in older buildings, the Liljendahl system costs far less than the conventional system, because fewer structural alterations are required.

Because of the vacuum, a leak in a pipe will cause air to be sucked in, instead of effluent leaking out. This eliminates the risks of pollution and objectionable odours.

Plastic pipes reduce noise disturbance inside the building, since they do not transmit as much sound to the frame as cast iron piping.

The waste from water closets produces practically the total quantity of pathogene bacteria normally existing in waste water in conventional sewerages. In the Liljendahl system there are provided separate discharge pipes for the water closet waste and the pipes for other waste water originating from bath tubs, lavatories, washing basins etcetera. This latter waste may be used without any inconvenience for agricultural irrigation or for infiltration purposes.

The Liljendahl system concentrates the pollution. Because so little sewage water has to be purified, when purification is necessary, the treatment plant can be built for less than the cost of a conventional plant. Furthermore the plant can be designed to permit almost complete purification as well as retention of the nutrient salts. High-grade fertilizers can be made by these salts by drying and pulverization: in this form they are practically odourless and hence saleable.

Certain test plants of different types have been carried out to obtain practical experience of the Liljendahl system before exploiting the system on a large scale. As an example, the new system has been applied in a cottage district since 1959 and has since then been operating continuously in a very satisfactory way. Now the new system is being installed in buildings of different types.

Many countries have expressed the wish to be allowed to use the Liljendahl system, and it will most certainly be used all over the world, when modern and hygienic residential areas are to be constructed.

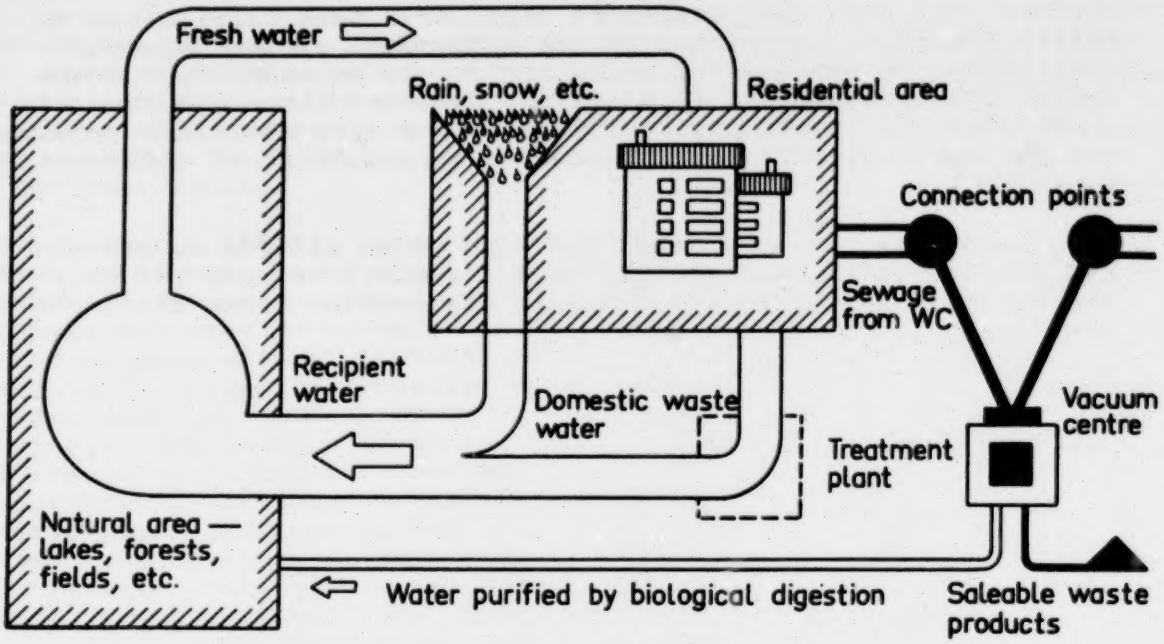

Figure I : Skeleton drawing showing the Liljendahl sewerage system for a residential area

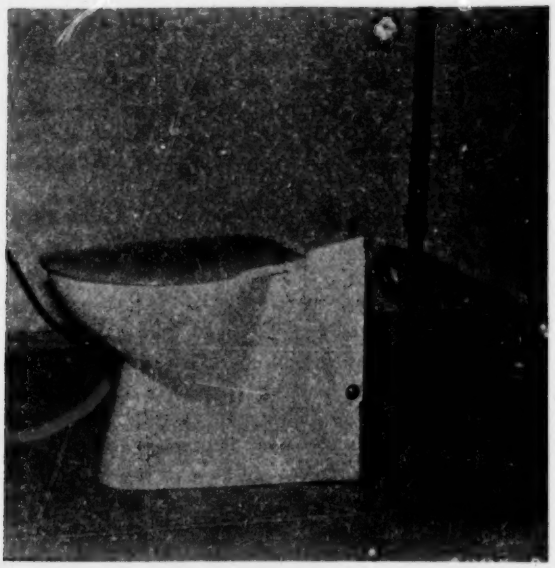

Figure II: The new type of WC-stool, from which the sewage - due to the existence of a vacuum - is carried by air

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Agenda Item: A.3.4.2

Netherlands

SOME SPECIAL ASPECTS OF THE COMBINED POWER AND SEA-WATER CONVERSION PLANT AT ARUBA, N.W.I., WITH A VIEW TO THE PARTICULAR MERITS OF COMBINED PROJECTS FOR DEVELOPMENT PROGRAMS IN GENERAL

By Dr. E. WEGELIN,
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No. 612

A.3.4.2.

by

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A. Introduction

At Balashi, Aruba, in the Netherlands West Indies since a few years a combined power and sea-water conversion plant is turning out distilled water for the governmental water supply as well as for the local Lago Oil Refinery together with a substantial amount of electric power, generated by the steam that is used ultimately in the water distillation plant. The actual net capacity of the whole complex amounts to 2.7 million g/day of distilled water plus 10.000 marketable kilowatts.

With an annual precipitation below 33 cm the isle of Aruba constitutes a typical example of an isolated extremely arid country, comprising 170 sq. kilometres of land, entirely deprived of any natural water supply. Consequently its 54.000 inhabitants have to rely completely on converted sea-water for all their domestic as well as industrial needs.

The new combined power and fresh water plant to be described briefly in this paper has resulted in a considerable cost saving as compared to the cost that would have been involved in producing the same amounts of power and of fresh water in two separate plants. For that reason this plant has been chosen by the authors of this paper to present the case of reducing total production cost by appropriate planning and combined installation of such important means of development as water and power supply.

In addition the possibilities will be pointed out of further combinations including the latest tool in saline water conversion, electrodialysis. Though such combinations have not yet been applied in actual practice, a substantial reduction in cost is to be expected particularly in areas where complete new developments are to be laid out.

B. Description of the Balashi Plant

200.000 lbs/h of steam are raised (generated) in one of two Babcock & Wilcox boilers, the second one serving merely as standby. At 875 lbs/sq. inch and 820°F this steam enters into two generators of rated capacity

10.000 kVA each. At a power factor 0.75 the corresponding rated energy capacity will amount to 15.000 kilowatts. Boiler make-up is distilled water obtained from the evaporators.

The steam leaving the turbines at an exhaust pressure of 1.4 kg/cm2 is used for evaporation of the sea-water to be distilled. The actual distillation plant comprises five sextupel effect evaporation units, having a capacity of 540.000 g/day of distilled water each.

The total plant was designed for a steam economy of about 5 lbs of distilled water per pound of steam (134 k.cal/kg of water). The above steam economy, together with the values quoted for throttle and exhaust pressures and temperatures will result in the required ratio between energy and water production. This ratio should be based on reasonable expectations as to the future needs of energy and water.

Each evaporating unit comprises seven shells, together constituting the six effects, the fifth effect having been carried out in the form of two shells. Actually in the fifth effect the sea-water temperature reaches a value of 65°C above which precautions are to be taken against scale formation. This is done by means of the so-called "scale master", an electrolytic device providing for the addition of an appropriate amount of $FeCl_3$ produced on the spot at this very fifth effect by electrolysis consuming an iron anode.

The evaporators are of the submerged coil type.

The feed is sea-water, 29°C, filtered only through a wide mesh metal gauze. The waste brine is leaving the plant at 75.000 p.p.m. at 130°F. The distilled water, pH 5.5 and containing less than 5 p.p.m., is given a final polishing treatment before delivery.
For about half the total quantity, which is delivered to the Lago Oil Refinery, this final treatment is restricted to the addition of a small amount of caustic soda and of sodium hexa-metaphosphate. The remainder to be delivered for domestic use is led across a coral lime stone bed improving the taste, the pH is raised to 8.3 by means of sodium carbonate after which a slight fluoridization is applied. The usual chlorination was not considered necessary since the distillate has been exposed to rather high temperatures.

The maximum load of the evaporator (425 tons/h) is reached at a steam rate of 87 tons/h (i.e. just below the full steam capacity of the boiler: 200.000 lbs/h or 90 tons/h).

The steam rate at full load of the back-pressure turbines is reported to amount to 7.11 kg/kWh of steam (1).
Hence the maximum energy production will amount to about 12.500 kilowatts. The energy requirements of the auxiliary equipment are 1.500 kW for the 5 evaporators and 1.000 kW (8% of the total production) for the power station. This leaves a net production of 10.000 kilowatts.

The ratio between the potential water production capacity and the potential energy production capacity has been chosen considerably higher than the ratio between present-day water consumption. In the years to come, the energy consumption is expected to increase more rapidly than the water consumption. In order to adjust the plant to the present ratio part of the high pressure steam is now bypassed and its pressure simply reduced to the value of the exhaust pressure so as to cope with the need of the

evaporators.

The above data have been extracted from the literature mentioned under 1), 2), 3) and 4), to which interested readers are referred for further information.

C. Advantages of the Balashi plant over a separate power plant and water distilling plant of the same capacity.

It may be of interest to compare the actual cost and energy consumption etc. of the Balashi plant with the values of the corresponding parameters in the case of two separate plants, one for water supply and one for power supply.

In drawing up an appropriate basis of comparison the following considerations have been taken into account.

In the Balashi plant conventional submerged coil evaporators have been applied, this method of evaporation being the only really foolproof method at the time the plant was designed. Nowadays in many cases flash-type evaporators appears to be preferable. A combined power and water supply plant with multiple flash evaporation is under construction at the isle of Curaçao today (5).
In actual practice sea-water evaporators should not operate at too high temperatures because of the risk of scale formation. Two kinds of scale may occur viz. on the one hand alkaline deposits and on the other hand calcium sulphate deposits. The formation of alkaline deposits can be suppressed at low cost e.g. by means of the "scale master" device applied in the Balashi plant. This does not hold for the calcium sulphate deposits. Without entering into the complicated solubility diagrams and the kinetics of the formation of the various modifications of calcium sulphate, we can state that among other things the negative solubility product of calcium sulphate and the specific power consumption of the evaporator will set limits to the maximum values of the allowable concentration factor and temperature. These values can be exceeded only if either all the calcium ions or all the sulphate ions are removed in advance, a rather expensive procedure. Consequently sea-water evaporators can be operated only with low pressure steam e.g. 1.5 atm.

The cost of steam, however, does hardly depend on the pressure at which the steam is generated. Hence follows the obvious conclusion to generate high pressure steam first for the production of mechanical energy and to use the exhaust steam in a water evaporation plant. The resulting combination of a power plant using back-pressure turbines and evaporators will turn out water and energy more cheaply than a separate water and a separate power plant can do. The marked difference between the two cases will be clear from the data listed in table 1. For the sake of simplicity all these data relate to continuous full load operation.

Table 1

Comparison of characteristic data for a combined power and water supply plant and for separate plants.

	Combined back-pressure turbine and evaporation plant (Balashi, Aruba).	Calculated separate water plant and power station (assuming 30% overall efficiency and power factor 0.75.)
Kilowatts generated	12.500	12.500
Kilowatts used in power section or station	1.000	1.000
Kilowatts used in evaporation plant	1.500	1.500
Marketable kilowatts	10.000	10.000
tons/h of fresh water produced	425	425
Necessary amount of heat (k.cal/h), to be supplied as fuel	80.10^6 (steam generator efficiency assumed at 85%)	116.10^6
steam generators	2 units 90.000 kg/h output each	2 units 90.000 kg/h output each for evaporator plant; 2 units 50 t/h each for power plant.
Turbines and generators	2 back-pressure turbines + generators 7.500 kW (10.000 KVA each)	2 condensing turbines + generators 7.500 kW (10.000 KVA each)
Evaporators	5 sextupel effect evaporator units, 85 t/h each.	5 sextupel effect evaporator units, 85 t/h each.
Total investment cost	$ 12.500.000.—	$ 16.000.000.— (estimated).

Hence it appears that the total cost of a water distillation plant and a separate power station with an output equal to that of the Balashi plant would have required 145% of the investment spent in the Balashi plant. Furthermore the separate plants would take up 128% of the energy consumed by the Balashi plant.

D. Advantages that may be obtained in similar plants by means of other combinations, including electrodialysis.

As has been shown above the Balashi plant constitutes and example of an efficient combination of power generation and water production. For that reason we have chosen this case to demonstrate to what extent even more efficient combinations are possible now that only a few years have elapsed since this plant was designed. To that purpose we shall consider a fairly different lay-out, including some other methods of desalting.

In the Aruba case 145 t/h out of the total amount of 425 t/h of fresh water produced are supplied to the Lago Oil Refinery whereas the balance (i.e. 280 t/h)are used for domestic purposes (local drinking water supply). This means that in fact 145 tons/hour of pure distilled water are needed as against 280 t/h of drinking water that should meet the standard requirement of salt content below the 500 p.p.m. mark.

Hence one might consider to apply distillation combined with back-pressure turbine power generation to the production of these 145 t/h only. Like in the present plant we shall assume a steam economy of 4.88 lbs of distilled water per pound of steam, which means that 30 t/h of steam (i.e. 27.4. 10^6 Kcal/h of fuel in the case of a steam generator efficiency of 85%) are needed for this purpose. Using the same steam rate as in the Balashi plant the corresponding energy figures are estimated to be:

Kilowatts generated	:	4.300
Kilowatts used in power section	:	350
Kilowatts used in evaporator plant	:	500
Marketable kilowatts	:	3.450

In the present Balashi plant 87 t/h of steam are necessary for the production of 425 t/h of water. Starting from the same quantity of steam we find that after spending 30 t/h of steam for the purpose described above a balance of 57 t/h (52. 10^6 Kcal/h at 85% steam generator efficiency) is still available for other purposes. Now let us assume that this quantity of steam is used entirely in an appropriate power station equiped with condensing turbines. At 30% efficiency the yield will amount to 18.600 kilowatts. If 1450 kilowatts are spent in the power station the net output will be: 17.150 kilowatts.

Together with the net output of the back-pressure turbine generators, this means a total output of 20.600 marketable kilowatts.

At Aruba under present-day conditions an amount of 10.000 marketable kilowatts is necessary. This leaves a balance of 10.600 kilowatts available for the production of the 280 t/h of drinking water, or 38 kWh/m3 of fresh water. Now with this amount of energy available another modern method of sea-water conversion viz. Multiple Ion Exchange Membrane Electrodialysis (M.I.E.M.E., (6) appears to be entirely adequate. The M.I.E.M.E. process, that has matured in recent years, can easily produce drinking water from sea-water at an energy consumption not exceeding the 38 kWh/m3 mentioned above. Admittedly, the water produced will not have the extreme purity of distilled water, but it will be immediately suitable for drinking water (i.e. salt level below 500 p.p.m.) without any further treatment.

Hence with the above combination exactly the same output as required from the Balashi plant can be obtained at exactly the same fuel consumption. The corresponding total investment, however, will be lower than the total cost of the Balashi plant as will be specified hereafter.

The total cost involved in the combined evaporator plant + back-pressure turbine power station together with the condensing turbine power station can be estimated at about $ 7.000.000.- .

The production of 280 t/h of fresh water from sea-water by the M.I.E.M.E. process at an energy consumption of 38 kWh/m3 will involve an average current density of 25 mA/cm2 and an overall current efficiency of 80%. For the capacity required 22.400 m2 of electrodialytic net cell pair area will have to be installed. If a unit price of $ 180.- a square metre of net cell pair area (including all auxiliaries) is assumed the total investment will amount to about $ 4.000.000.- .

This brings the total investment for the schedule described up to . . . . . $ 11.000.000.-

instead of the $ 12.500.000.-

spent on the present plant.

In other words a saving of over 10% on the cost of investment would have been accomplished.

The conditions at Aruba cannot be considered to be representative for the conditions in less developed areas. It is more likely that in general in such areas the need for water meeting the required 500 p.p.m. salt level for domestic purposes will be absolutely predominant as compared to the need for extremely pure boiler feed or chemical process water. If the aim would be to merely provide 500 p.p.m. class water the prospects offered by the application of some recent developments of science and technology would be even more impressive.

This can be illustrated by the following calculation of a hypothetical case of a total fresh (i.e. 500 p.p.m.) water output equivalent to that of the Balashi plant (425 t/h).

Consider a case where the installation of a large power station (of at least 100.000 kilowatts output) is justified (needed). Such a station would be most likely a very high pressure power station in which the so-called re-heat principle would be applied. Furthermore a fairly constant continuous load is assumed. Under such conditions a 40% efficiency can be obtained. Hence in this case 80. 10^6 Kcal of fuel will generate about 37.000 kilowatts of which 3.000 kilowatts are to be spent on the power station itself, leaving a net output of 34.000 kilowatts.

Now - for the sake of comparison - we shall use these 34.000 kilowatts for the supply of 425 t/h of fresh (500 p.p.m.) water and 10.000 marketable kilowatts. This leaves 24.000 kilowatts available for water desalting with the M.I.E.M.E. process or 56 kWh/m3 of fresh water. In this case the load (current density) of the electrodialysers can be increased approximately by a factor $\frac{56}{38}$ which means that the total amount of membrane area (net cell pair area) and consequently the investment will be reduced by the corresponding factor $\frac{38}{56}$, so that the investment for the sea-water conversion plant will amount to about $ 2.700.000.- .

The proportional share in the investment necessary for the power station is estimated at about . . . . . $ 6.300.000.-

for the 34.000 kilowatts mentioned above, so that the total investment works out at . . . . . $ 9.000.000.-

This figure is 28% less than the . . $ 12.500.000.- figure for the corresponding Balashi plant.

Actually the figure of 80.10^6 Kcal of fuel constitutes an arbitrary figure that has been adopted only for the sake of comparison with the Balashi plant.

Upon complete optimalization of the system as a whole, taking into account capital cost as well as running cost for both the power generation and the saline water conversion a lower optimal load (current density, energy consumption) is to be expected.

The description of a detailed optimalization would go beyond the scope of the present paper. It can be easily shown, however, that if the energy consumption mentioned in the first example (i.e. 38 kWh/m3) is maintained also in the present case, the total investment involved in power generation and saline water conversion will stay rather close to the $ 9.000.000.- found before. However, now the total energy consumption will amount to 425 x 38 - 16.150 kW.

Together with the 10.000 kW required, this corresponds with a total fuel consumption of 61.10^6 Kcal/h in the first case. In other words the combination described above might yield not only a 28% saving in investment cost, but also about 25% saving in energy cost.

Consequently, very roughly speaking, a 25% reduction in total cost might be expected.
In this connection "total cost" means the joint cost of power and fresh water. Whether one wishes to make this profit result in a lower water price or in a lower energy price or both is a matter of price policy, not of technology.

Selfevidently all the cost figures used for the high pressure turbine high capacity power stations and saline water converters. They will not hold for small installations though even in that case the qualitative trend will be the same.

In the present paper a specific case has been considered by way of example. A more general treatment of the profits obtainable by appropriate combination of power generation and saline water conversion has been given by one of the authors in an earlier publication (7).

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Agenda Item : A.5.1.4

New Zealand

TRAINING OF GEOLOGISTS AND MINING ENGINEERS AND SUPPORT PERSONNEL IN NEW ZEALAND

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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TRAINING OF GEOLOGISTS AND MINING ENGINEERS AND SUPPORT PERSONNEL IN NEW ZEALAND

by
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1. New Zealand offers four universities with fully staffed, well equipped and active Geology Departments where academic training of geologists to Ph.D. level is available at accepted international standards.

2. There is a tendency for these departments to specialise in some independent branch of the subject, although this does not result in any marked transference of students from one University to another when seeking higher degrees. Otago University has always been famed as a petrological and mineralogical school, and this tradition with structural petrological thinking has been maintained. Canterbury has traditionally been a school of paleontological studies and has recently extended its activities into the field of sedimentation, with the aid and support of the New Zealand Geological Survey in establishing a joint laboratory. Wellington University lays considerable stress upon field mapping and structural geology, with recent attention being devoted to microfaunas. The latest addition to this department at Wellington has been a Senior Lecturer in Soil Science. Auckland University has maintained the broad aspect of structural geology based on petrology and field mapping. These courses are interleaved with considerable field work and field geology. Geological mapping is taught generally in conjunction with field excursions, but a more formal course is available at Wellington.

3. No formal training is available in geophysics, although the Physics Departments do provide some aspects of geophysics, generally upper atmosphere. Extra curricula lectures in earth geophysics are given by members of the Geophysics Division of the Department of Scientific and Industrial Research.

4. Under-graduates can advance to a degree of B.Sc. with Honours in Geology, and then proceed to M.Sc. with distinction, or directly to Ph.D.

5. As a consequence of the high level of University geology teaching and post-graduate research, employers of geologists in New Zealand are able to draw on a pool of recruits who are academically well equipped and thoroughly acquainted with their discipline. Those who are particularly interested in making geology a career and who are

doing post-graduate work have usually sought vacation employment with the New Zealand Geological Survey in order to gain some experience of a working geological institution. The New Zealand Geological Survey is able to offer vacation employment to students in the field and in petrology and paleontology laboratories. This allows the student to gain working experience; it teaches him professional mapping techniques, techniques of fossil preparation, and of petrology and mineralogy preparations and determinations. It gives him an insight into indexing methods and data recording, particularly of fossils, rocks, and minerals. In the field the student gains an insight into methods of field mapping, the use of air photographs, recording of data, and keeping of record sheets. At the same time the New Zealand Geological Survey is able to evaluate the student as a potential recruit. As a result, this is a most effective means of recruiting. The obverse holds in that the student can decide for himself whether or not the type of professional life the Geological Survey offers is to his liking. The cordial relationships between University geology departments and the New Zealand Geological Survey operate to the good of geology as a whole and must owe much to the lucky accident of the relatively small geographic size of New Zealand having within its geology a continental complexity.

6. New Zealand can supply a training to geologists which can be a combination of academic work of a high standard with field and practical work in the New Zealand Geological Survey. This training would equip any newly-formed geological survey with officers having a background of practical work and a scientific knowledge of a high order.

7. On the mining side, a degree B.E. or M.E. is gained from the University of Otago School of Mines; an Associateship (A.O.S.M.) is also provided. The mining course covers a wide curriculum of mechanical engineering, mining practice, ore dressing, and economic geology and other basic science subjects. This course is associated with mandatory practical work in mining. Unfortunately there is very little mining activity in New Zealand other than coal mining, and the tendency is to acquire practical work in the Australian metal mines. Nevertheless, there is a very high standard of training given and the resulting graduates possess a reputation throughout the world.

8. University graduates from newly-emergent countries who are unable to obtain proper field experience or experience in laboratory techniques in geology can obtain this training in New Zealand. The New Zealand Geological Survey can provide the opportunity for young geologists of newly-formed geological surveys to receive field training, training in field mapping, the use of air photographs, and other field techniques, together with laboratory training in various techniques of petrology, mineralogy and paleontology. New Zealand has some advantages in this field; it can offer very interesting and complex geology, and it has a small geographic compass. In addition it offers scope for geological surveys in emergent countries as they are likely to be of comparable size to the New Zealand establishment. If young students were to obtain field and institutional training in some of the geological surveys of the larger industrial countries, they possibly would be impressed by the wealth of instrumentation of such surveys. This is a dangerous course, particularly when many countries newly

attached to the United Nations have yet to complete their basic geological mapping. For this purpose no great instrumentation is needed but the stress is on the field geologist who goes out in the field and looks at rocks in the field.

9. For the purposes of this paper support personnel are assumed to be non-academically-qualified people whose interest and enthusiasm is in the field of geology. A number of these people are employed by the New Zealand Geological Survey and many of these technicians have shown great ability and adaptation, have developed special techniques and have become authorities in a particular subject. Some have even gone so far as taking a particularly specialised aspect of the work and studying it at professional level. A few have finally transferred to the professional division without having taken any academic course. Support personnel, however, generally remain as technicians but as time goes on they usually develop into a field of their own (water supply geology, fossil seeds, Recent foraminifera - to name but a few), where they work to a professional standard.

10. In New Zealand this development among technicians is encouraged and in several districts technicians are able to take over water supply work, mineral sampling, coal sampling, and a number of other tasks thus allowing the professional officers to devote more time to research aspects.

11. The New Zealand Geological Survey can provide support personnel training in the major sections of a modern geological survey.

(a) Field Geology. While assisting field geologists there is ample opportunity to gain experience in methods of collecting, packing, marking and preserving specimens. Elementary field mapping over a variety of scales, and the use of air photographs as a mapping tool are also subjects in which experience is available. This is coupled with petrological and paleontological collecting and the sampling of industrial minerals and rocks.

(b) Petrology and Mineralogy. Training is given in methods of sampling, crushing and preparation techniques for subsequent mineralogical examination. Experience is gained in the use of a wide variety of techniques in cutting, grinding and mounting thin rock sections and in polishing and mounting ore specimens for examination under reflected light. Elementary mineral separation can be carried out using mechanical, magnetic electrostatic and heavy liquid methods, together with the operation and use of X-rays with powder samples. Experience in the use of punch cards for recording petrological data can be obtained. Elemental mineral determinations can be made using optical methods.

(c) Paleontology. In macropaleontology training in the use of the techniques of cleaning and recovering specimens, in the methods of preparing plaster, rubber latex or vinyl casts and moulds is available. In micropaleontology, study and practice in methods of breaking down sediments mechanically, chemically, and with sonic vibration is available. There is also opportunity to undertake preliminary selection and methods

of mounting. In the study of fossil botany training can be had in the techniques of breaking down of carbonaceous sediments, and the separation and final mounting of fossil spores and pollens.

(d) Cartography. Training in methods of compiling field sheets from a variety of base maps and air photographs is given. Opportunity is available to study layout and preparation of illustrative work leading to higher grade cartographic colour work.

(e) Library. There is opportunity available to train in the work of a specialized library in cataloguing and circulation together with literature search to assist professional officers. To those wishing to advance in this section, attendance at the National Library School can be facilitated.

12. The whole question could be summed up by saying that training in New Zealand arises from a first class academic course obtainable at any one of four Universities. This course has a long tradition of very able and eminent geology professors, and today is seeing an expansion in teaching staff that enables a very broad curriculum to be undertaken, at the same time permitting staff to undertake research to the benefit of the faculty as a whole. The cordial relationships between New Zealand Geological Survey and the University geology departments enable students to undertake vacation work in the field or in the laboratory, thus gaining valuable training in the applied aspects of their work and at the same time learning what it is like to work in a national geological organisation. The end product of this method is a geologist academically qualified to a high degree and as experienced as he can be in the various methods of field and laboratory geology.

13. Where this training cannot be obtained locally the New Zealand Geological Survey is quite prepared to provide it for geologists from the geological surveys of the smaller, newly-emergent countries.

14. Support personnel can also be training with the New Zealand Geological Survey in all laboratory preparation techniques connected with paleontology, micropaleontology, palynology and petrology. These are developed to a very high order in the New Zealand Geological Survey and some technicians have already published papers on new techniques they have developed. Field technicians also can receive training that will include sampling, surveying, use of air photographs, and the recording of field data.

15. We in New Zealand can offer this training at a very high level and in a country where the geology is sufficiently complex to give a student a wide variety of experience. At the same time he would work with a geological survey of the size comparable to that which some of the newer countries will need to accomplish their basic geological mapping which is fundamental to their industrial well-being.

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Sweden

EXPLORATION AND DEVELOPMENT OF MIDDLE SIZED UNDERGROUND MINES

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Exploration and development of middle sized under ground mines

by Ingemar Pousette
General Superintendent
Boliden Mining Company

An ore body can be defined as a deposit of metal mineral which can be economically worked, beneficiated and realised. The world's ore reserves are therefore not entirely dependant upon the deposit's grade and the mineral concentrate's selling price, but upon the capital which must be invested in prospecting, exploration, development, mining and mineral dressing.

Large deposits with low grades can often be exploited, thanks to the low mining costs that occur with large enterprises whereas small ore bodies, such as the Scandinavian sulphide deposits, have higher costs per ton and therefore demand higher metal grades.

However, relatively small and low grade deposits can be mined, especially if one company is responsible for the exploitation of several such units.

The Boliden Mining Company is working 15 ore deposits of which the majority have an annual production of less than 200.000 tons. The deposit which last came into production, and those which are now being explored, are in the size range 1-3 million tons.

The ores which have been found by the company's prospecting department are not considered part of the ore reserves

before their size and grade have been determined through comprehensive drifting and diamond drilling. This exploration, which is conducted to increase the ore reserves, is a part of long term planning to maintain a suitable supply to the mineral dressing plants.

The characteristics of the Scandinavian sulphide deposits - thin steeply dipping lenticular or tabular bodies, sometimes deep - require very comprehensive exploration before it can be definitely said wether or not they are workable. With this the most costly work is the sinking of an exploratory shaft 300-400 meters deep.

A special method has been developed for doing this type of exploration of which an account will be given here. The aim has been to shorten the time required for this underground exploration and to invest as little capital as possible in the plant in case the investigations should give a negative result.

Since company long term mining policies may mean deferring actual exploitation of proven ore for as long as twenty years, it is naturally advantageous that capital should not be tied up in surface plant during this time. In addition, the plant would probably become obsolete before mining is resumed. Consequently for exploratory underground work the surface plant comprises lightweight portable units.

It can also happen that the deposit may prove too small to justify the expense of a permanent plant. In this case, the entire ore body could be extracted using the small portable plant.

Should the exploration programme indicate that the deposit is not economic or if extraction of the ore is not commenced immediately, the entire surface plant can be moved to its next destination. Only some small concrete foundations remain as a monument to unfulfilled hopes.

Two such installations are now in operation and are briefly described. As a large part of the plant is embodied in the form of carriages, reminiscent of a circus environment, the name "mine circus" is applied to the installations.

The head frame, of which there are two types depending upon whether one or two head sheaves are used, is a 30-meter-high tripod, with legs constructed of prefabricated sections. These are made of prefabricated tubular lattice girders of a maximum length of seven meters. It has a total weight of 15,3 tons and is designed for a pay load of 16 tons. After the tree concrete foundations are poured, erection takes only a few days.

The 365-h.p. hoists is of eight tons capacity and has a rope speed of four meters per second. The ultimate hoisting depth is 625 meters which is sufficient for normal requirements. The hoists is bolted down on a concrete slab. The motor-generator set and contact breaker unit is mounted on a carriage, located in the hoist room. The pre-fabricated sides and roof of this building are of galvanized corrugated sheeting.

The switchboard and 10000/380 volt transformer are installed in a carriage having a wheel base of 6,9 meters and a width of 2,3 meters. The transformer of 800 kVA capacity operates at a frequency of 50 c/s. The switchboard is divided into high-tension and low-tension compartments.

Compressed air is supplied by three compressors, also mounted on carriages. There are three identical carriages with a 3,5 meter wheel base and a width of 1,8 meters. Installed on each is a compressor with a capacity of 10,6 cubic meters per minute at a delivery pressure of eight atmospheres.

Aerial Cableway

When a full bucket is hoisted to the top of the headframe

a dumping door automatically falls out over the shaft. The rock is emptied into a bin and passes via a shaking feeder to a measuring bin of 1,9 tons capacity. This bin discharges into a 1,1 ton bucket of an aerial tramline.

The aerial cableway has a 42 mm diameter track cable, one end of which is attached below the headframe and the other is anchored on the far side of a 19-ton 60-meter high pylon of pipe construction. The pylon is guyed with two side stay lines. It is built of 10 meter long prefabricated sections.

The aerial dumping bucket has two wheels running on the cable and is moved by a 17-mm diameter pull and return rope operated by an automatic hoist. The hoist is placed on the far side of the pylon whilst the control equipment is beside that for the shaft hoist in the operator's cabin. The 80-h.p. hoist has a rope speed of 3,4 meters per second. Capacity of the tramway when the rock pile is 170 meters from the shaft is 40 tons per hour.

The bucket is bottom-opening, the trap door being opened by a tripping device suspended from the track cable. When it becomes necessary to move the dumping point the tripper is shifted to the desired position by a 5 mm-diameter wire rope and a hand winch. Between the shaft and the pylon, a distance of 220 meters, there is sufficient capacity for about 200.000 tons of broken material.

Other Prefabricated Carriages

The two hoist houses, shaft house and water pump house are constructed of light sections which are easily fitted together. The rest of the buildings come as prefabricated carriages.

The carriages are built of watertight plywood on a bolted framework, the outer wall being covered with "Boliden"

impregnated panels. They have the following dimensions: length 9,8 meters, width 2,4 meters; and height 3,3 meters. For transport, these carriages are put on simple trailers and at the site they are placed on four timber sleepers thus raising them 30 cm off the ground. The air heating system comprises a fan behind each carriage in a row of five, which draws warm air through a pipe from an oil-fired boiler. The hoistman's carriage has a separate boiler.

The work shop carriage is furnished with all the standard equipment needed for the repair and maintenance of drills. It also serves as a store for spare parts.

Amenities in the refreshment carriage include refrigerator, oven, stove, three tables with four chairs per table and at the far end a 2,5 by 2,0-meter rest platform, on which the workers can lie down during their break.

There are two identical changing room carriages with washroom each having accommodation for twelve men. The carriage contains a drying stand for waterproof attire, a boot scrubber and drying rack, twelve ventilated lockers for ordinary clothes, a stand for mine clothes, a washroom with a 300-litre immersion heater, and two showers.

The mine captain's office, with work tables and cupboards, is situated in a carriage together with two small stores and a small changing room containing a bench, a shower and five lockers.

The hoistman sits in the end section of a carriage with the control and signal equipment for both hoist and aerial cableway. The rest of this carriage is subdivided into a shiftboss's office and a lamproom for 30 lamps where the time clock is also housed.

Other Installations

A large shed beside the shaft contains equipment continually

needed in the shaft, such as pipes, pumps, concreting frames, sets, and drills. This building also contains sharpening facilities for drill steels, a 5-ton overhead crane, storage space for electrical and other equipment and a rescue depot.

Sand and gravel are stored in a heated bin. From a 250-litre mixer, concrete is introduced directly to a 0,6 cu. meter skip through a pipe.

The shaft sinking method devised by Boliden is such that a sinking rate of about 40 meters a month can be attained at reasonable cost, which is considered satisfactory. This rate is exclusive of cutting stations but includes placing concrete rings , bolting wire mesh to the shaft wall, and installing shaft services. On this basis, the aim is to complete the sinking project at as low a cost and with as small a crew as possible. Sinking is carried out on three shifts in such a way that a 2,4 meter round is drilled and blasted in the first shift and mucking and other work is performed in the remaining two shifts.

As a rule shafts are sunk to a depth of 400-450 meters at a diameter of 4,6 meters. Drifts are driven at 50-meter intervals from which diamond drilling is immediately carried out to ascertain the grade and extent of the ore. If results are disappointing, shaft sinking is discontinued until the problem can be more carefully studied and a decision made either to proceed or to abandon the project.

To mechanize drilling in this undertaking, a circular drill rig is used which enables one man to operate two machines for a certain portion of the drilling. Mucking is done with a Cryderman shaft mucker.

At present the labour force comprises three men per shift

in the shaft, a hoistman, a shiftboss and on the day shift a fitter who looks after the machines, sharpens drill steel, etc. The three workers at the shaft bottom achieve a sinking rate of about 20 cm per manshift inclusive of construction work and bolting wire mesh to the walls.

Shaft sinking is a specialized job which requires experienced personnel, and therefore to avoid the necessity of training men at the various mines, there is within the company a special shaft sinking department. At the present this department is responsible for three sinking operations, one in Kristineberg, one in Udden and one in Långdal and expectations are that crews will be fully occupied for many years ahead.

Fig. 1 A general view of the shaft sinking plant at Näsliden, where a 440 meter shaft was recently sunk by Boliden. From left to right - five portable carriages, shaft house, headframe and dumping arrangement, hoistroom, two compressor carriages and water pump house.

Fig. 2 Another view of the plant at Näsliden showing the dumping arrangement and the cable for the aerial tramway.

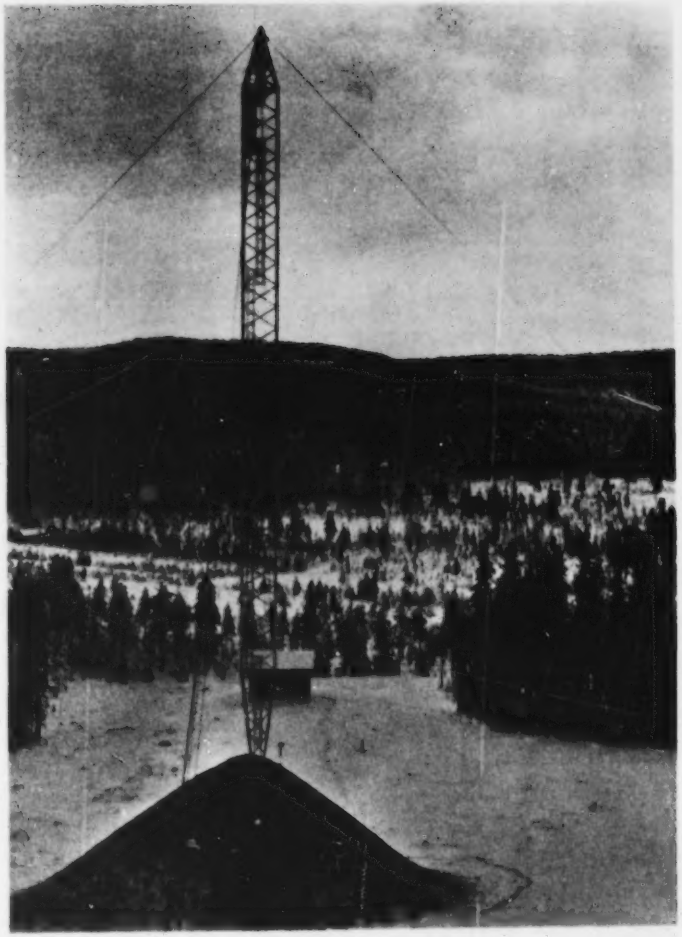

Fig. 3 The pylon for the aerial tramway is constructed of prefabricated sections. The dumping bucket runs on a cable and is moved by a pull and return rope. The hoist house for this can be seen behind the pylon.

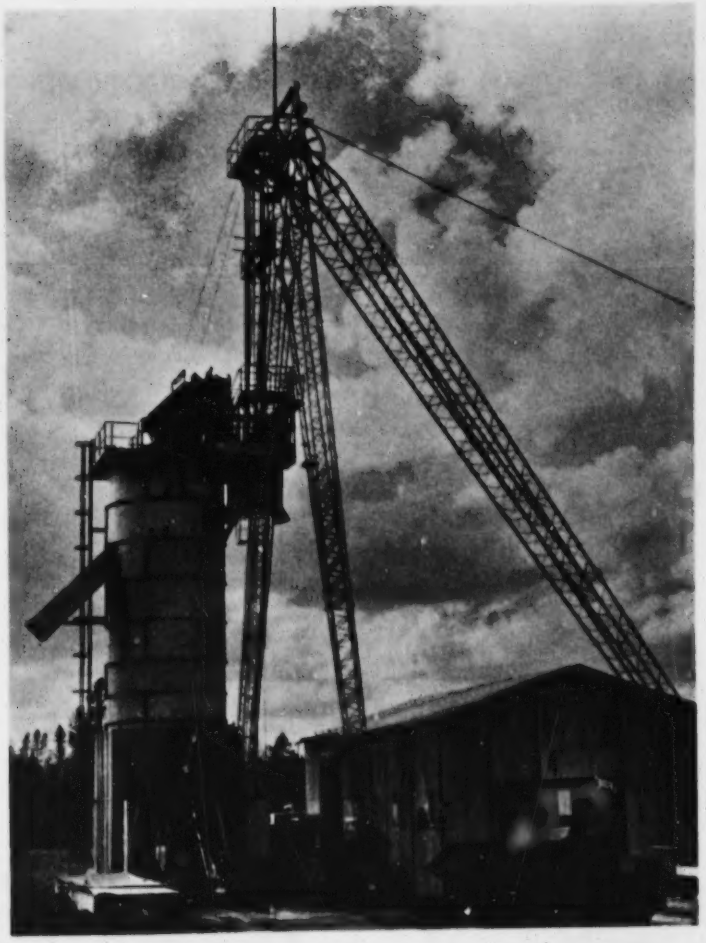

Fig. 4 At the shaft sinking plant at Udden the bucket is emptied into a bin. The waste rock is taken away by truck and used for building a road to another deposit.

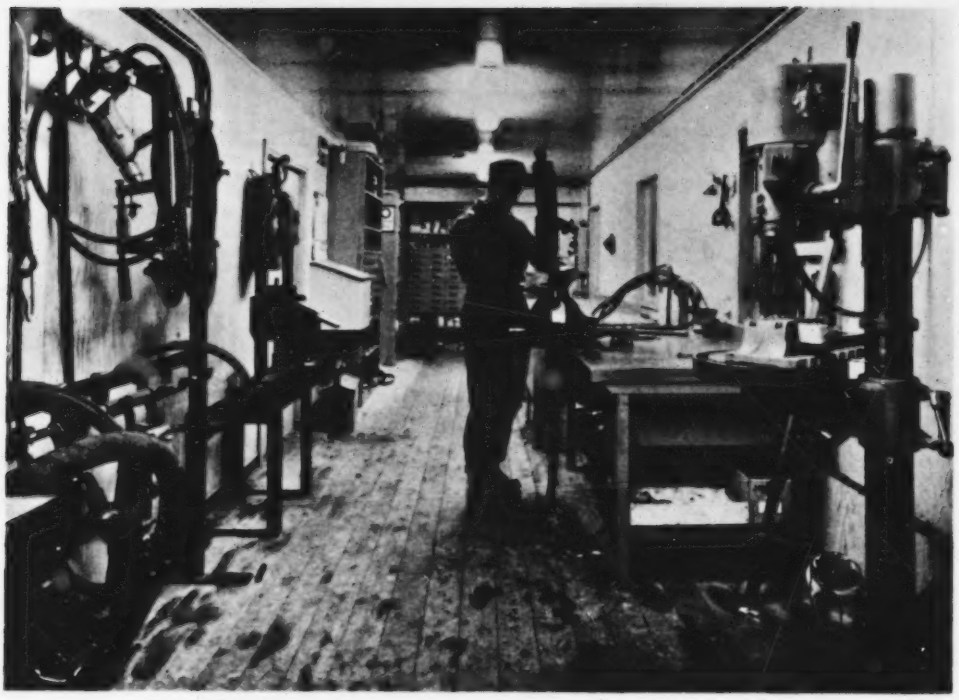

Fig. 5 The workshop, which houses standard equipment for the repair of drills, contains also a small store for spare parts.

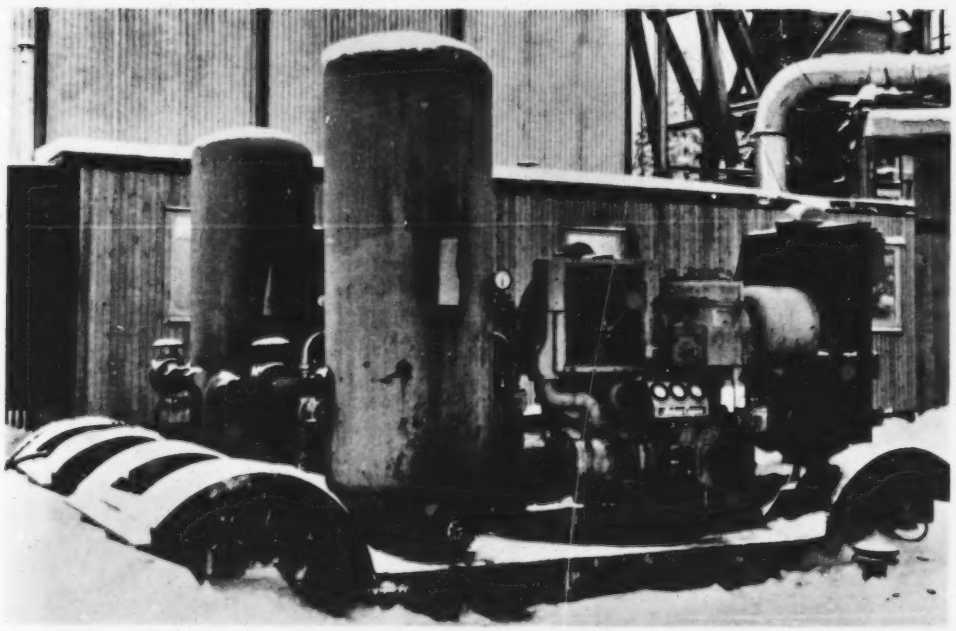

Fig. 6 Two of the aircooled compressors on their carriages. At the site the wheel axles are removed and the carriages placed on timber sleepers.

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Agenda Item: A. 3. 4. 1

United Kingdom

THE USES OF BITUMEN IN HYDRAULIC ENGINEERING

By Baron W. F. VAN ASBECK,
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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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THE USES OF BITUMEN IN HYDRAULIC ENGINEERING

by

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(Shell International Petroleum Co., Ltd., London)

INTRODUCTION

(1) The development of modern methods of refining crude oils has opened up many diverse fields for the use of the large quantities of bitumen now produced and available the world over. One of these fields is that of hydraulic engineering, where the versatile product bitumen is now being used, as such or in asphalt compositions, as a building material of specific technical value and of relatively low cost in all climates, both above water to high altitudes and under water to considerable depths.

(2) The object of this paper is to give a short review of a choice of applications of bitumen in hydraulic engineering that may be of benefit to less developed areas if used to suit local circumstances.

IRRIGATION CANALS

(3) Aiding the advance of agriculture in many areas of the world are modern systems of irrigation. An essential feature of a successful scheme is to reduce seepage losses of valuable water to a minimum when on its way through canals from source to field. This purpose can be achieved in various ways with bitumen in diverse forms of application.

(4) In existing earth canals or in old, concrete-lined canals, seepage losses of water can be reduced to a minimum by temporarily closing the canal in sections to reduce the velocity of the canal water and then applying a slow-breaking bitumen emulsion which will gradually close the pores in the soil as the canal water percolates through the earth or concrete-lined perimeter of the canal.

(5) Again in existing canals the same purpose can be achieved by lining a canal in service with overlapped prefabricated reinforced asphalt mats or rolls, laid under water.

(6) The former principle of using prefabricated, reinforced mats is suitable also for waterproofing canals in the dry, in which case the mats are generally jointed with an asphalt compound. This method is particularly suitable for small jobs where access to the canal through fields is difficult.

(7) A low cost method of rendering a dry canal waterproof has been devised by the U.S. Bureau of Reclamation, Denver, Colorado, and is used extensively in the arid parts of the U.S.A. It consists of overexcavation of a canal, trimming the perimeter and spraying hot blown bitumen to a thickness of 6 mm. This bitumen membrane is then buried under a layer of the overexcavated material at least 30 cm. thick to protect it against possible mechanical damage or being destroyed by hooves of animals.

(8) A bitumen membrane has also been successfully used in Pakistan as a waterproofing medium to a thickness of 3 mm. in the age-old method of canal lining interposed between two layers of brick tiles measuring 30 x 15 x 5 cm.

(9) For canals where the surface to be covered is of sufficient importance to bear the cost of installing a hot-mix asphalt installation as used for road work, the application of an asphaltic concrete or a sand asphalt lining is the most effective construction. This is a surface lining laid to a thickness of at least 4 cm. The hot-mix asphalt material is laid by hand or mechanically and then completed by rolling. It renders not only the canal perimeter impermeable but has some additional advantages. Firstly, from a hydraulic point of view, one advantage is that an asphaltic concrete lining is smooth, the coefficient of roughness of the surface being 0.015 for Manning's Formula, and another is that it can be laid in a parabolic form to obtain maximum flow capacity of the canal for a minimum cross-section. This type of lining is continuous as it is laid without joints, it is sufficiently plastic and flexible to follow natural settlements of well-designed and compacted stabilized soil fills without losing its properties of resistance to creep on a slope and of strength to withstand movement of heavy animals, if applied to the required thickness. Since asphaltic concrete is a visco-elastic type of material it is clear that drainage should be provided for where hydrostatic uplift and undue deformation of the lining might otherwise occur and than an effective soil sterilization should take place (such as a 5% solution of sodium chlorate in water sprayed at a rate of 2 litres/m^2) to prevent weed-growth through the lining. A final, but not less important, advantage is that hot-mix asphalt linings can be laid at competitive cost as compared with other materials. These asphalt linings have been in service for more than 20 years without requiring practically any maintenance.

(10) A number of sand asphalt canal linings have been laid in Egypt with very satisfactory results for large extensions of irrigation areas in the lower Nile valley.

LARGE DAMS AND RESERVOIRS

(11) The energy resources of an area must generally be developed in order to tap a country's full potential, and hydro-electric power as a basis for industrial expansion can contribute to the national wealth in many instances. Dams and reservoirs must be built for the conservation of water needed for the exploitation of hydro-electric schemes and hot-mix asphalt materials play their part as impermeable courses or structures in retaining the water in the required quantities for use at times specified for a correct functioning of the delivery of electricity.

(12) The standard example of the construction of an impermeable asphaltic concrete layer on the upstream surface of a rock-fill dam is that of the Ghrib Dam in Algeria. The 25th anniversary of the historical event of the first filling with water of the great valley closed by the dam should not be allowed to pass without mentioning the name of Mr. G. Drouhin, former President of the International Commission on Irrigation and Drainage, to whose initiative during the preliminary design period and later on during construction the complete success of this first important asphalt dam construction is mainly due. A performance of a total water seepage of a pail of water per minute for a dam of 62 m. maximum height at very low annual maintenance costs can hardly be surpassed. The initial cost of the two-course asphaltic concrete layer of 12 cm. total thickness was also much lower than estimates for other materials showed.

(13) On rock-fill and earth-fill dams built in later years the upstream face is generally not so steep, the usual practice being to form a slope of 1:1.75 maximum and preferably 1:2. Separation of control drainage pipes for possible seepage water through the asphalt surface, under the dam and round the abutments is always advisable for more rapid location and assessment of seepage which normally would have to be followed by repair work.

(14) Although the construction of an impervious facing to a dam has the advantage of being easy to lay and to repair, if necessary, and can serve simultaneously as a protective layer it is, of course, more vulnerable to damage and destruction than an impervious core. The principal advantage of an impervious facing is, however, a matter of dam stability in that the whole body of the dam remains permanently dry, whereas the upstream side of the impervious core of a dam is generally saturated, resulting in a lower density of the component materials and consequently a lower resistance to shear. A third possibility of placing the impervious structure is in an intermediate position as a sloping construction. The latter is built up at the same time as the dam proper, to a width of at least 1.20 m. for constructional reasons, by vibrating boulders of similar size as used for the dam proper into consecutive layers of rich asphaltic concrete by means of special vibrating devices. In this way an impervious screen is formed by a skeleton of boulders between which the voids are filled with the asphalt material thus forming a mass of a stability at least equal to that of the dam itself.

(15) It is an acknowledged fact that earth and rock-fill dams are normally built where the bearing capacity of the soil is low but the cost of earth movement by modern large capacity equipment is decreasing to such an extent that their construction may be preferable also in other conditions. These two types of dam fit more naturally in the configuration of surrounding soil than slender concrete dams, their width at the bottom and abutments ensure greater resistance to movement and piping and they can even contain an impervious asphalt facing as well as a semi-pervious asphalt core of boulders and open-graded asphalt material such as bituminous macadam. The object of the latter is to have a braking effect on the rush of water through a rock-fill dam in case it is severely damaged on the upstream side. The consequences of an unexpected failure in the dam or its junctions to the adjacent soil should always be seriously considered and the possibility of reducing the energy of the rushing water following a sudden local break in a dam by means of a semi-porous central asphalt screen may be of great value where a dense population or a valuable agricultural or industrial area would otherwise be endangered.

(16) This type of construction would seem particularly of value in countries where earthquakes occur.

(17) As regards reservoirs built in soil for hydro-electric purposes, many of which are located in less favourable surroundings than those built in earlier years, particularly those of the compensating reservoir type, need durable solid linings. It is becoming evident that the established method of lining is with asphaltic concrete applied in a two-course layer with staggered joints to a mimimum compacted total thickness of 7 cm. on a levelling course or drainage course of bituminous macadam. For further technical considerations and details of construction, reference can be made to previous paragraphs.

RIVER BANKS

(18) Although river training works are not frequent in less developed areas and are limited to certain sections of water courses, concave river bends may need strengthening of river banks to protect adjacent cultivated land, industrial or residential areas and engineering structures such as roads, railways and abutments of bridges against erosion and floods. A strong and durable asphalt bank protection requiring little or no maintenance is the asphalt-grouted rubble or stone revetment. It consists of hand pitching grouted or penetrated with a sand mastic, that is a rich sand asphalt applied hot by gravity flow from a bucket or container through a steel chute. The thickness of the revetment depends on local conditions but may vary from 30 cm. to 1.00 m. for torrential streams carrying large boulders. A strength test was carried out on the River Arc in France recently to demonstrate that an asphalt grouted hand-pitching of 50-60 cm. thickness would resist the impact of boulders weighing from 800 to 1,600 kg. falling from a height of about 12 m. without showing more than a scarred facing.

NAVIGATION CANALS

(19) In European countries many long-service asphalt canal linings and bank revetments exist but this type of construction is only exceptionally needed in less developed areas. The type of structure used for this purpose is either an asphaltic concrete revetment or an asphalt grouted hand pitching as described in the previous paragraphs.

HARBOUR MOLES AND DAMS

(20) The first harbour dam was built 15 years ago in the Netherlands consisting of a sand core built according to the hydraulic fill process by pumping water and sand through a pipe, the sand being deposited in very compact formation at the end of the pipe and the water draining off gradually. The protection of the dam consisted of a sand asphalt layer provided with a seal coat of bitumen covered with sand. Only little maintenance work has been carried out from time to time. The established method of protecting dams of this type for the immense 25-year Delta Plan scheme consists at present of constructing an asphalt grouted hand-pitching under mean high water spring tide and above that level a dense asphaltic concrete revetment.

(21) A breakwater of a completely different type was strengthened many years ago by asphalt grouting the protection, consisting of 15-ton concrete blocks, of a vertical concrete wall. Rubble was dumped in the hot sand mastic as it flowed by gravity through a steel chute into the interstices between the large concrete blocks.

(22) Rubble mound breakwaters can be duly strengthened against storms by providing an asphalt grouted facing or cap covering the seaward side, crest and harbour side. The structure is not only made more resistant to breaking waves but turbulence is reduced by forming a streamlined construction. This is the basic principle of the success of this type of structure. The asphalt grouting material can be accurately placed above as well as under water level.

COASTPPROTECTION

(23) Sea walls protected by asphaltic concrete revetments or asphalt grouted hand pitching are now being built according to well-established methods of construction based on many years of experience. The methods of applying these asphalt constructions have been described in previous paragraphs. A fiThe illustration shows a typical example of one of the long sea walls built in Japan after heavy destruction was caused by typhoons in September, 1959. It shows the importance of providing protection to the rear side of the sea walls to prevent damage by waves washing over the crest which are always the initial cause of a breach, followed by complete destruction of the sea wall and flood disaster.

(24) Many years of experience combined with continuing research work in laboratories and field investigations on the characteristics and performance of asphalt constructions related to hydraulic problems such as wave attack, hydrostatic uplift and percolation of water are forming the scientific basis to ensure the success of the use of bitumen and its compositions for hydraulic constructions.

(25) The author is indebted to this United Nations Conference to have been invited to present this paper and trusts it will be to the benefit of the less developed areas.

Figure 1 - JAPAN : Nabeta Polder - Asphalt protection of rear side of seawall to prevent breaching

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A D D E N D U M

The contributor Government notifies the following corrections:

1. Add the enclosed photographs (II-XVI) which were previously omitted.

2. Note that Figure I refers to Paragraph 23 of the text.

Fig.II - Italy: Cremona.
Emulsion treatment of canal water

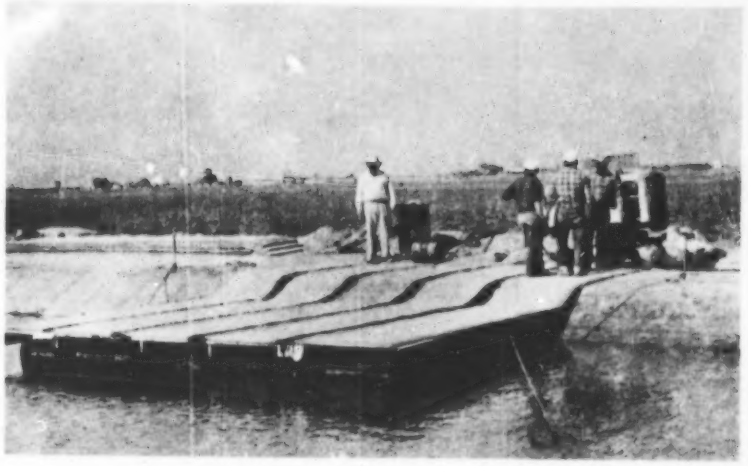

Fig.III - USA: Lining canal
with prefabricated mats

Fig.IV - France: Balgau. Waterproofing
in the dry with prefabricated mats

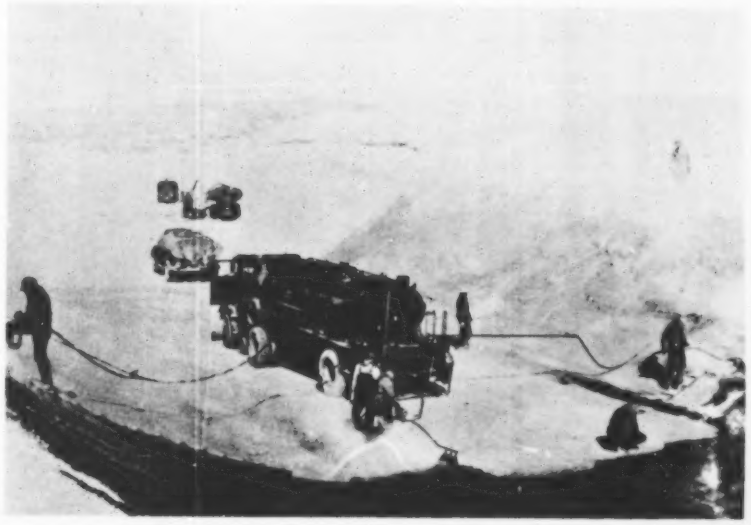

Fig.V - USA: Columbia Basin Canal, Washington.
Waterproofing by means of buried bitumen membrane

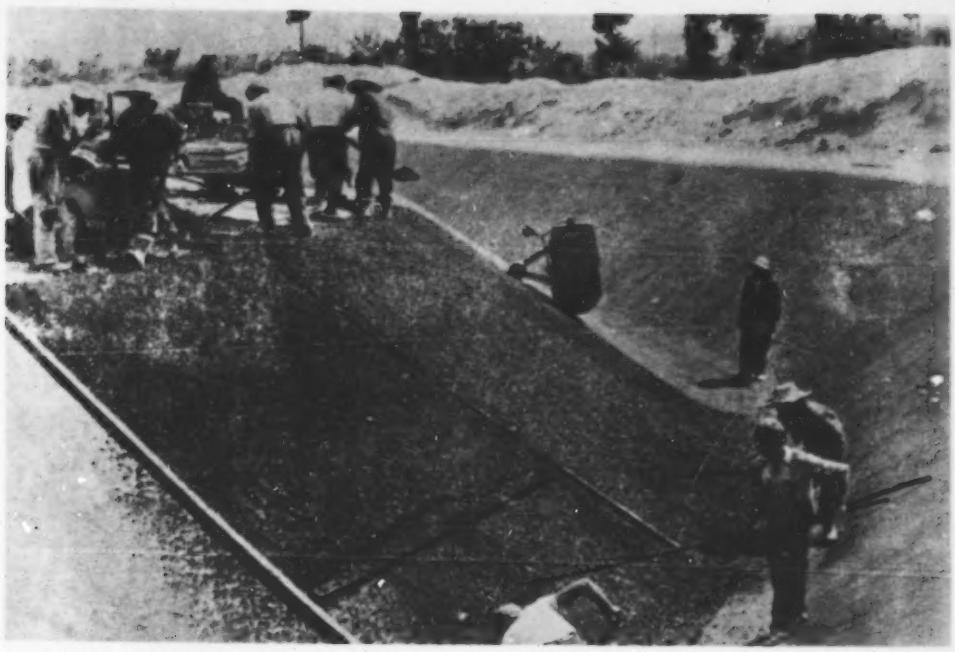

Fig.VI - Tunisia: El Aroussia Canal.
Laying asphaltic concrete canal lining by hand labour

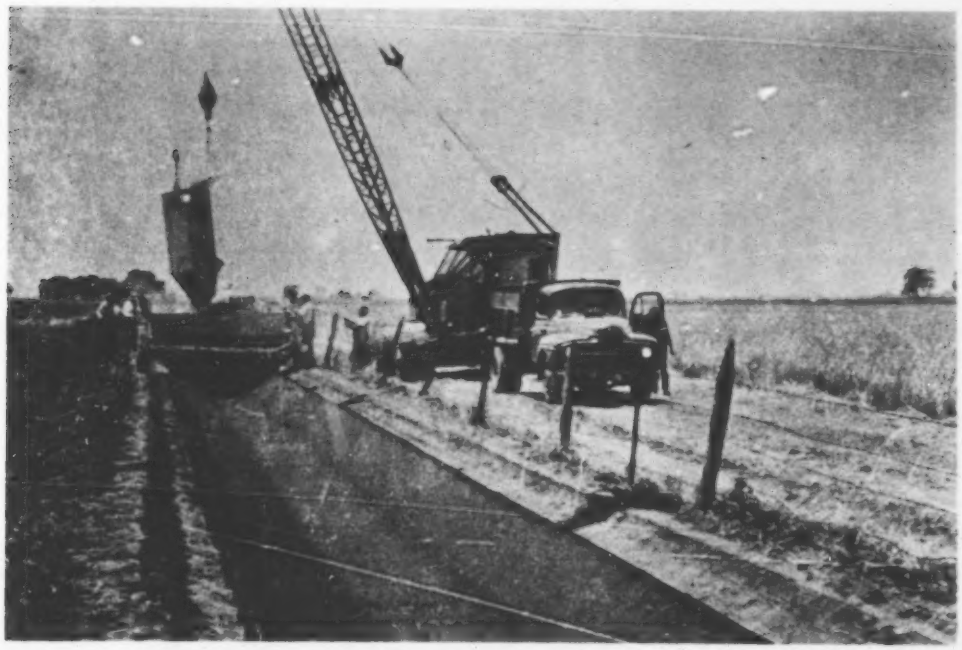

Fig.VII - Algeria: Atouta scheme. Mechanical excavation
and lining of canal with slip-form canal liner

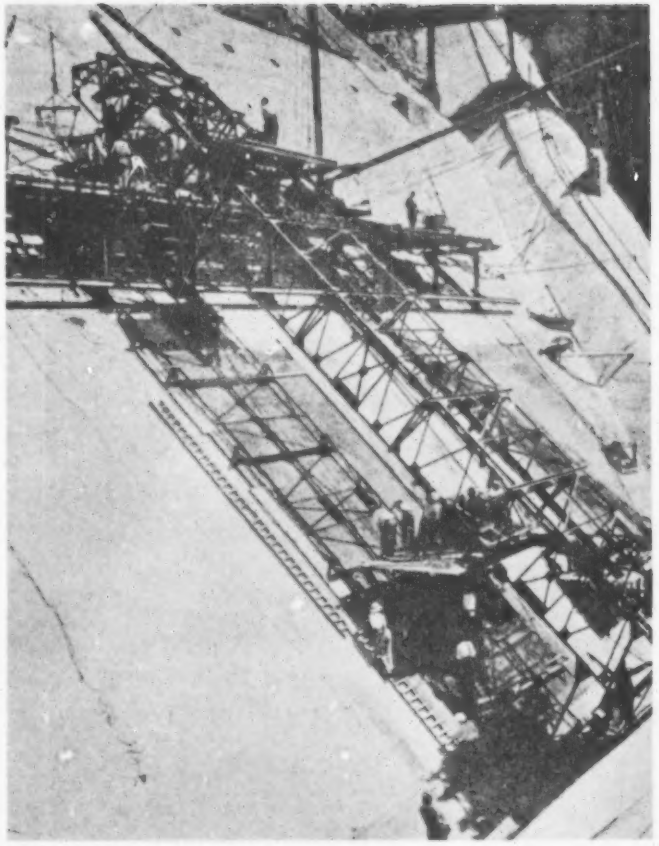

Fig.VIII - Algeria:Ghrib Dam.
Construction of impermeable asphaltic concrete layer on rock-fill dam

Fig.IX - Austria:Rotgüldensee Dam.
Construction of impervious asphalt core of a dam

Fig X - Germany : Hennetal Dam. Construction of a semi-porous central asphalt screen in a large dam to reduce energy of water and destruction in case of local breach in dam

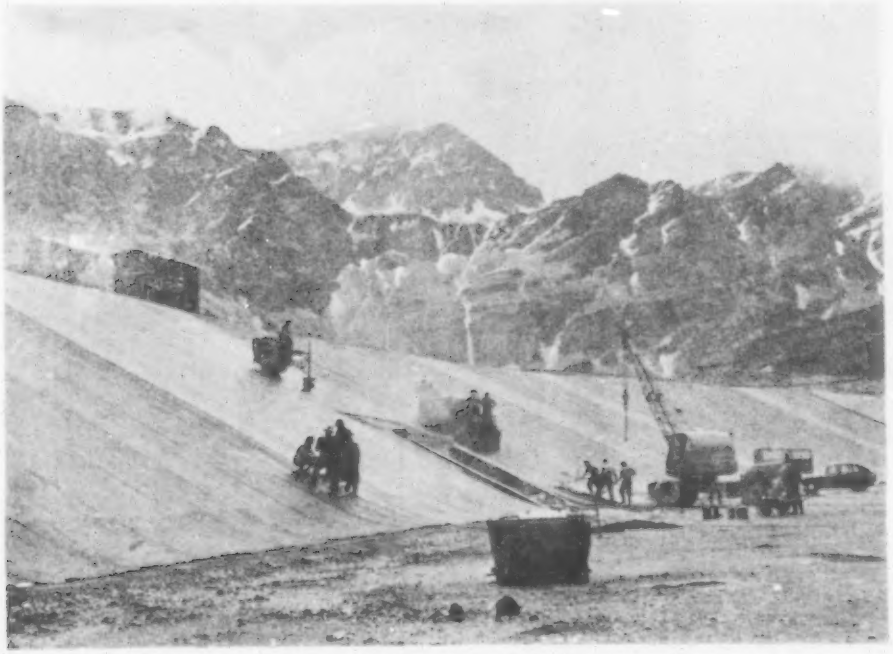

Fig XI - Switzerland : Wanna Reservoir. Construction of asphaltic concrete linings to compensating reservoirs has been established since 1938

Fig. XII - India:
River Torsa
Asphalt grouted hand-pitching on river bank

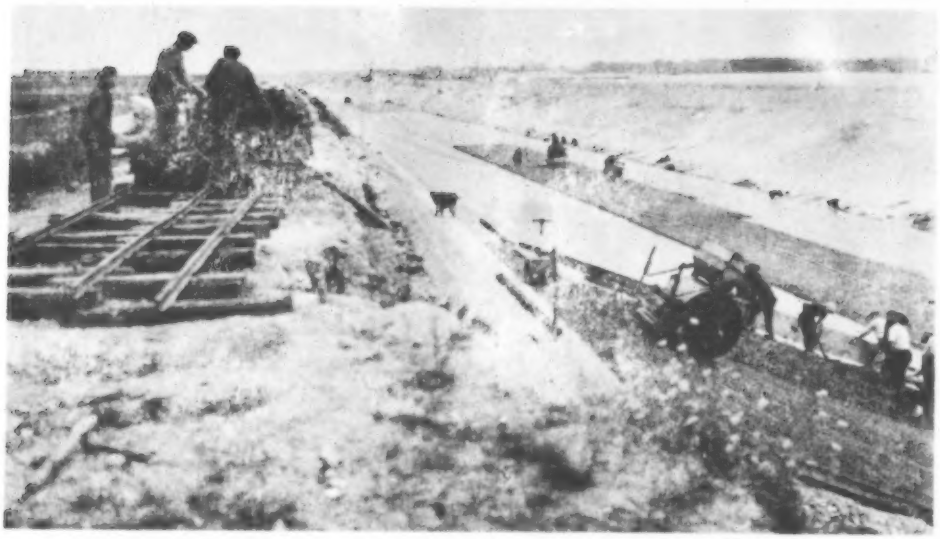

Fig. XIII - Belgium: Nimy-Blaton Canal - Laying asphalt lining in navigation canal (now in service for 25 years

Fig. XIV - Netherlands: Harlingen - Waves washing over harbour dam during a winter storm 15 years after construction

Fig. XV
France: Bayonne
Concrete breakwater strengthened by asphalt grouting

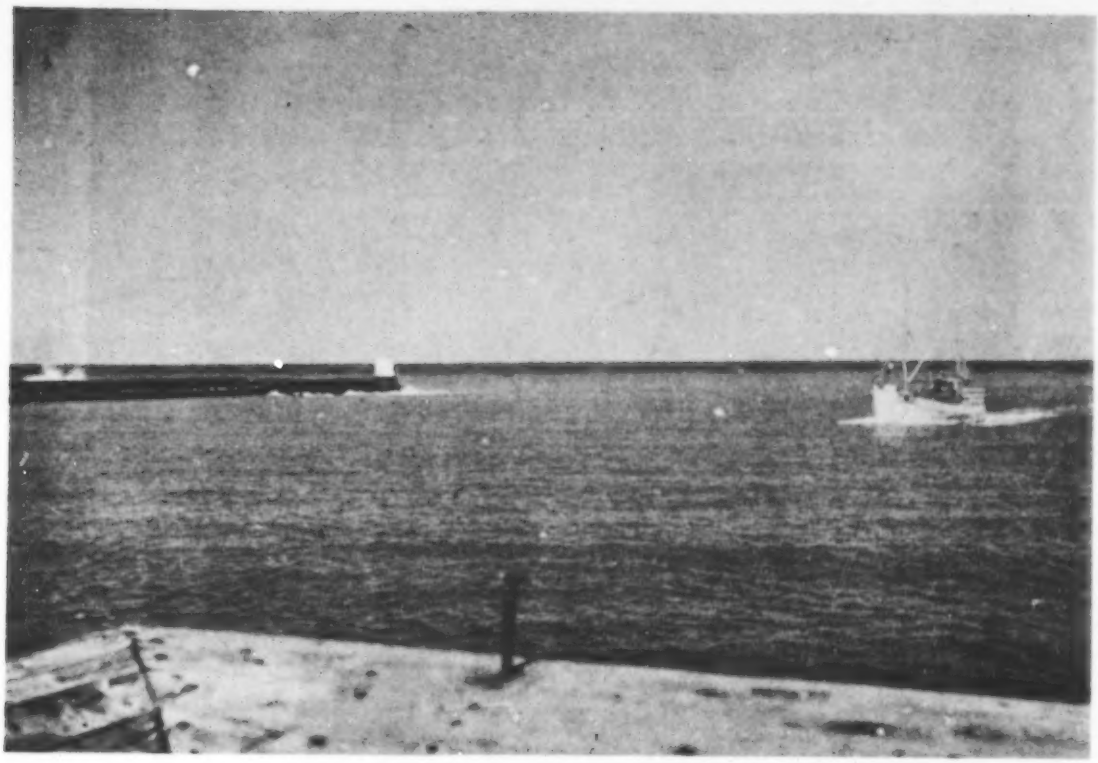

Fig. XVI - Denmark: Hirtshals - Asphalt grouted exposed end of harbour mole

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Agenda Item: A.3.2.2

Turkey

ESTIMATION OF RIVER FLOW AND IMPROVEMENT OF DATA COLLECTION

By T. DINÇER,
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Investigation and Planning Division
General Directorate
of State Hydraulic Works,
Ankara

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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ESTIMATION OF RIVER FLOW AND IMPROVEMENT OF DATA COLLECTION

by
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General Directorate of State Hydraulic Works, Ankara.

Introduction:

1. Turkey has a very wide range of climatic variations and thus deserves the name of Asia Minor, having all the features of a small continent. The average annual precipitation ranges from 200 mm. in the central plateau of Anatolia, to 3000 mm. in the Eastern Black Sea coastal region. On the mediterranean coast the growing season covers the whole year in contrast with the North-Eastern plateau of Kars where the growing-season is only four months.

2. The wide seasonal, yearly and area variations of climatic factors poses a variety of problems to engineers who deal with projects of irrigation, power and flood control. The estimation of river flow is one of these problems and the lack of reliable long-term records makes this task especially difficult.

A. General review of hydrometrical and meteorological network in Turkey.

a) History:

3. The systematic data collection in the field of meteorology in Turkey was begun about thirty-five years ago, when the young Turkish Republic established base meteorological stations in the principal cities of Turkey. River gauging began (with ten years of delay) in the middle of the 1930-1940 decade. Figure 1 shows the rate of increase on the number of meteorological and hydrometrical stations. The rate has been relatively rapid in the last few years, as engineers became aware of the importance of the meteorological and hydrological studies for the project investigations and project design.

b) Statistics:

4. Turkey has now 750 meteorological stations in operation 150 base stations are equipped with instruments measuring precipitation, temperature, atmospheric humidity, wind velocity, solar radiation and evaporation, 120 stations with recording precipitation gauges. The remaining 630 stations measure only the precipitation on a daily basis. Compared to the total land area of the country, there is about one station in 1000 km^2, the density being some what higher in

Western Turkey. The immediate goal should be to double this figure in five years to reach a satisfactory network density.

5. The meteorological stations in Turkey are established and operated by different agencies of the government. The main agency which is responsible for meteorological data-collecting is the Directorate of Meteorology, which operates about 650 stations, most of the other stations being operated by the State Hydraulic Works. This duplication is regrettable, but attempts are being made to unify the network.

6. The hydrometrical network consist of about 650 stream-gauging stations. This figure would be satisfactory if only good rating curves were available for all of them. At the present state about 150 stream-gauging stations have records of discharge, the others having only some discharge measurements and records of stages.

7. The hydrometrical network is operated by the Directorate of Hydro-Power Department and the State Hydraulic Works which have almost equal number of stream-gauging stations in operation. The same duplication unfortunately exists as for meteorological network but we are confident that in the near future stream-gauging network will be operated by a unique agency of the government.

8. As the needs of the country increase for natural resources development the data collecting work will have its right place among the other activities of the nation. It can be said rightly that the degree of civilization of a country is directly proportional to the measurements made in its borders.

B. Methods of River Flow Estimation:

a) Where long-term records are available.

9. It is unnecessary to say that where long-term records exist, there is but little difficulty left to hydrologist. However it should be stressed that even with fairly long records, problems of river flow estimation arise, as it was shown by Hurst in the study of the Nile Basin.

10. The two important estimates hydrologist has to make are the mean and the variation of the river flow. It is known that the reliability of a mean (the inverse of its standard error) is proportional to the square root of the number of observations for random events. But for natural phenomena as precipitation and river flow, this reliability grows slower than the square-root of the number of years of record as it was shown by several eminent hydrologists. This is why there is always interest to try to lengthen the records by correlation using precipitation and limnological records which generally cover longer periods of time.

11. The daily, seasonal and yearly variation of the river flow is another important factor in the hydrological studies. The design of the projects which use the natural flow of the rivers or stored water requires a good knowledge of this variation. The probability considerations which are formulated in the frequency analysis are of utmost importance. We like to state that the hypothesis which lies at the bottom of the so-called operation studies made using the actual records, is simply the exact reproduction of past records in the future. It is seen that this hypothesis do not have a logical basis. Efforts should be made in order to determine the most probable sequences of years which will occur in the future. Past records may contain some rare sequences of years to be eliminated by probability considerations. As we are confident that the probability of having head, while tossing a coin, even after ten heads are seen consecutively, is exactly 1/2 for the next throw, the hydrologist should try to understand the laws of probability which govern the stream flow, rather than use past records directly.

12. The determination of capacities for reservoirs is made taking into consideration the probability of the critical periods to be used in the operation studies. The solution of the problem is rather obvious in the case of the critical periods shorter than one year. A frequency analysis can be made in this case in order to determine a critical period with a given period of return. The problem becomes difficult with critical periods longer than one year, and the efforts to find a satisfactory solution to this problem was unfruitful.

13. It is unnecessary to say that these studies should be made on a basin-wide scale. Dimensionless capacity-draft curves are developed for several long-term stations and the mean of these curves is used to estimate the capacity required to regulate the stream flow. This curve may be used advantageously for the basins where there are only short-term records or no records at all.

14. Our experience in Turkey proved that the economical capacities of reservoirs generally lies between the average yearly flow volume and the half of this volume. Smaller reservoirs have problems due to the sedimentation and the bigger ones do not have economic justification.

b) Where only short-term records are available:

15. The correlation technique is extensively used in the hydrological studies in Turkey. The application of this technique, we like to stress, requires a good knowledge of statistics and the hydrological characteristics of the basins under consideration. Flow versus flow correlations are most generally used on a monthly basis and the relation proved to be generally linear. For rivers fed by the snow melt corrections are made where the flows are desynchronised by the effect of difference in altitudes. For the precipitation versus flow correlations it was found not that the non-growing season precipitation was the most significant variable to estimate the total yearly flow volume and again linear relations are most generally found, a fact that does not agree with theoretical considerations. In basins where the snow-melt is the dominant factor for the river flow the regression equations may be used to forecast the seasonal runoff, the winder precipitation, in this case, having a close relation with the water-content of the snow-pack before the melting season.

c) Where there are only spot measurements of discharge:

16. It is rather difficult to attempt a correlation analysis where only spot measurements of discharge exist. But if the station is not very far from a station with long term records satisfactory results are obtained. Figure II - shows such a correlation. If the spot measurements do not cover an important range of the stream-flow this technique may lead to misleading results, the relation for different rates of discharge being not the same.

17. Some times when only discharge measurements for minimum flows are available it is possible to make an estimate of the average flow by using the ratio of the mean minimum flow to mean flow. This ratio does not change much for large basins. For example for the Eastern regions the mean minimum flow is approximately one third of the mean flow.

18. The variability of the daily flows are estimated from the dimensionless discharge - duration curves developed using the records of the long-term stations. For this study log probability scale is used.

d)Where no records are available:

19. If the density of stream gauging stations is relatively high it is possible to estimate the runoff from an ungauged area by comparing the hydrological characteristics of this latter with the other gauged areas. In this study the precipitation records are of valuable help to hydrologists. The fundamental hydrologic equation, that is the relation Precipitation=Runoff + (Evapo-transpiration) is advantageously used. Evapo-transpiration may be estimated by analysing the data available for the gauged areas.

20. The other factors as geology, soil and vegetation cover the slope of the basin should be taken into consideration to reach a reasonable estimate of the runoff for the ungauged areas.

e) Critical review of methods of river flow estimation:

21. In the river flow estimation problem, as it is seen in the previous paragraphs, the most important factors are the reliability and the length of the records. But the extension and the interpretation of the records by using statistical techniques and basin wide studies also should be emphasised.

22. This is especially important for countries such as Turkey which do not have adequate records for hydrological studies. A good understanding of the probability and the regression theory is essential. There is no time to wait to obtain long-term records and unfortunately little help from the foreign experience. We welcome any method or suggestion which could help us in the improvement of hydrological studies made with short-term records or in the basins where no record is available.

C. Estimation of extremes of stream-flow:

a) Flood flows.

23. The estimation of flood flows present difficulties which do not exist for normal or minimum discharges. It is seldom possible to measure directly the high values of stream flow, the flood peaks for example, and a method of estimation is necessary. When a rating curve is available the logarithmic extension or Ad 1/2 method may be used. But there are cases where these methods fail, especially where the flood plain conveys a major part of the flood flow. The hydraulic characteristics of the gauging stations are an important factor for the extension of the rating curves. There is also an interesting chart developed by Langbein which gives good results to estimate the peak flood discharge. This chart uses the ratios of the mean daily discharges of preceeding and succeeding days to the mean flow of the day the maximum is observed. Figure III - shows the agreement of this method with the maximum discharges estimated from the rating curves.

b) Estimation of flood flows for the ungauged areas:

24. The estimation of flood flows for the basins where no records are available is made by using empirical formulae, developed by using the records of long-term stations. The general relation

$$\bar{Q}_{max} = CA^{2/3}$$

was found in a study made in a country-wide scale. In this formula $\bar{Q}_{max}$ is the yearly mean flood peak discharge in $m^3/Sec.$, A. the effective contributing drainage area in km^2, and C, a regional constant which varies between 1.0 and 5.0 for Turkish rivers. The variability of yearly floods are estimated from the records of long-term stations and an average coefficient of variation is applied to the ungauged areas. The method developed by Dalrymple is used for the basin wide studies. For the frequency analysis Gumbel's method is preferred to the methods which include a coefficient of skew.

c) Small basin subject to warm-season convective storms:

25. One of the most difficult problems in flood flow estimation are the small basins subject to warm-season convective storms. These storms cover an area of about 500 km^2 and gives exceptionably high flood peaks. The duration is in the order of several hours and it is impossible to estimate the discharge by using the rating curves or direct measurements. The use of slope-area method is necessarily imposed.

26. The use of crest-staff gauges has just begun in Turkey and the establishment of 100 gauges in the next year is planned. We hope that in this way we will obtain interesting results in the small watersheds by using the slope-area method.

27. It is also difficult to make a frequency analysis for this type of flood. When such a storm hits a basin one should wait another five years to experience another similar phenomenon. The yearly-flood method is inadequate to handle this problem. If we had a long-term record - 100 years for example - we could very well study these floods on a five-year basins and have about 20 points to plot on the probability-paper. The work continues to estimate this type of flood using the precipitation records and combining the records of several

stations (ergotic hypothesis).

d) Estimation of spillway design floods:

28. The estimation of spillway design floods is made using envelope curves for the most critical floods experienced in the past. This method is, of course, a very rough one but we believe that with a careful study of the basin it is possible for an experienced engineer to make a reasonable estimate. The frequency methods are especially avoided in these estimates. The unit-hydrograph method is naturally better to solve this problem, but our attempts did not reach satisfactory results, due to the lack of adequate precipitation and stream-flow records.

e) Estimation of minimum flows:

29. As for the flood flows the estimation of minimum flows is generally made by an extension of the rating curve. To avoid this, it is desirable to make direct measurements for minimum discharges This is not a difficult problem, because the duration of low stages are much longer than the high stages.

30. A fact which is generally overlooked when the site of a gauging station selected is the so-called sensibility of the station. As it can be seen easily the sensibility of a station is directly proportional to the roughness of the river bed and inversely proportional to the width of the river bed and the water surface gradient. There is always interest to select sites with good hydraulic characteristics to have a sensible stage-discharge relation and this is especially important in the case of minimum flows.

D. Importance of adequate data collection and improvement of methods of estimation.

a) Base Stations:

31. Time sampling is made by the base stations. There are about 100 base gauging stations in operation in Turkey. These stations are established mostly in large basins and are equipped or being equipped by automatic recording instruments.

b) Secondary stations:

32. These stations are established to make the area-sampling and following the requirement of the projects under consideration. They are generally equipped with simple staff gauges, and some are being equipped with crest-staff gauges.

33. The establishment of experimental watersheds has just begun in Turkey. Such basins are equipped with a dense network of precipitation gauges and a base meteorological station with a gauging station equipped with automatic recorder.

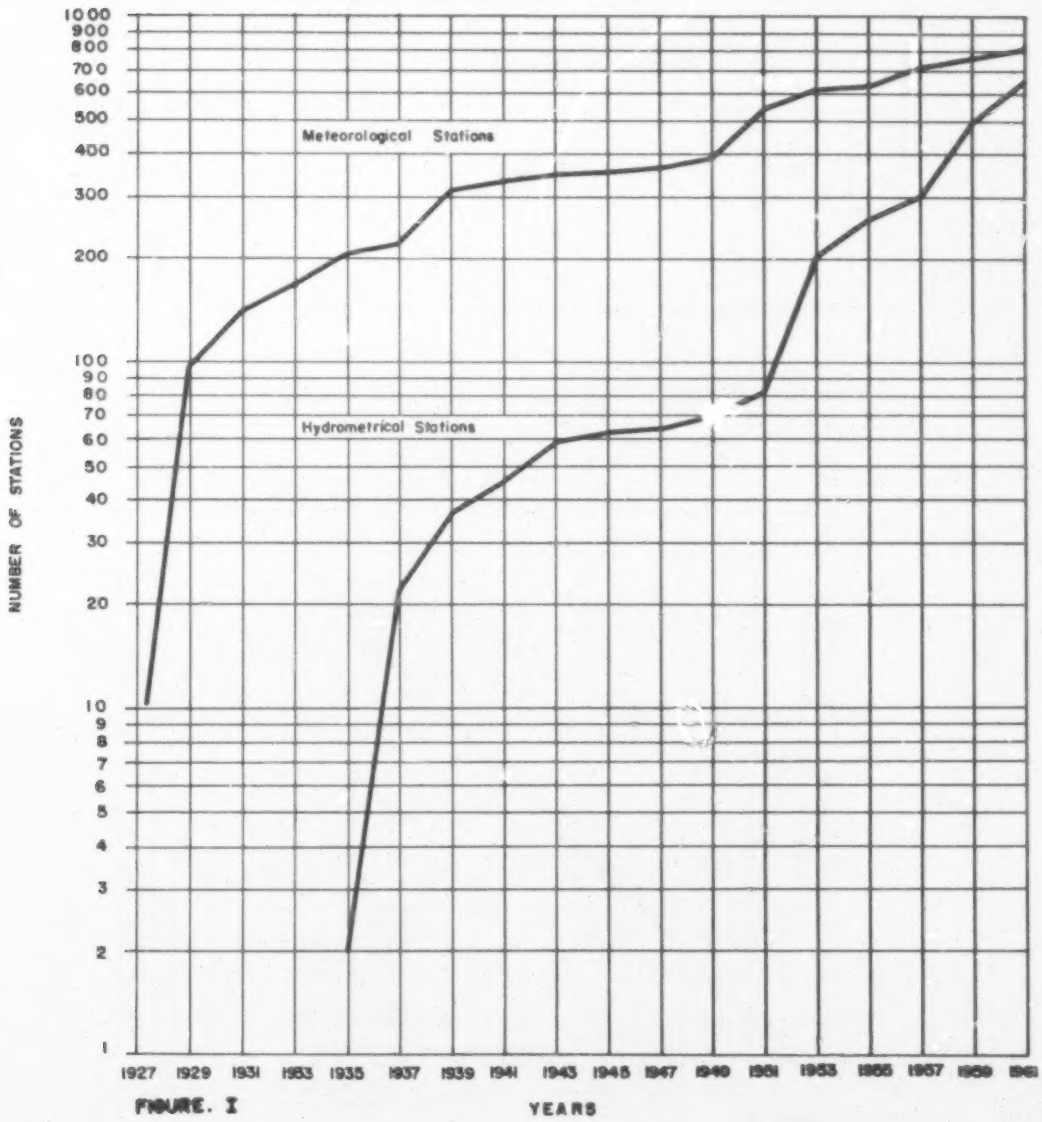

FIGURE. I

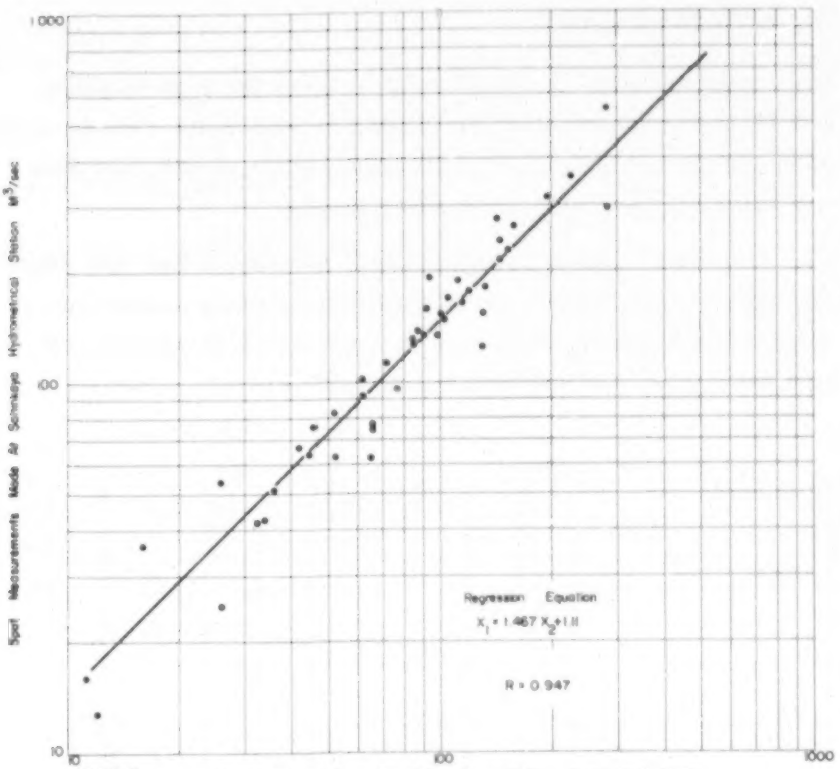

FIGURE . II Daily Discharges Obtained From The Rating Curve At Kanp Hydrometrical Station

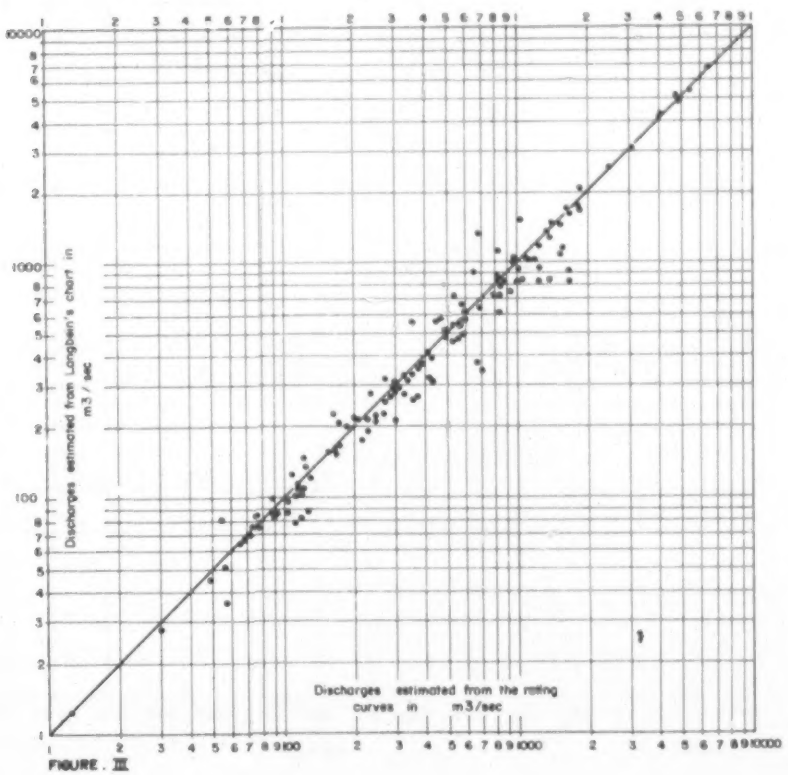

FIGURE . III

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